NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

AIR SAMPLING SENSORS, THE OPEN SKIES TREATY, AND VERIFYING THE CHEMICAL WEAPONS CONVENTION

by

Gregory D. Rowe

December, 1995

Thesis Advisors: James J. Wirtz
Peter R. Lavoy

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis
4. TITLE AND SUBTITLE Air Sampling Sensors, the Open Skies Treaty, and Verifying the Chemical Weapons Convention - UNCLASSIFIED		5. FUNDING NUMBERS
6. AUTHOR(S) Gregory D. Rowe		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.		
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

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14. SUBJECT TERMS Air sampling sensors, Open Skies Treaty, Chemical Weapons Convention, verification			15. NUMBER OF PAGES 98
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

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AIR SAMPLING SENSORS, THE OPEN SKIES TREATY, AND VERIFYING THE CHEMICAL WEAPONS CONVENTION

Gregory D. Rowe
Lieutenant, United States Navy
B.B.A., University of Notre Dame, 1988

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF ARTS IN NATIONAL SECURITY AFFAIRS

from the

NAVAL POSTGRADUATE SCHOOL
December 1995

Author: Gregory D. Rowe

Approved by: James J. Wirtz, Co-advisor

Peter R. Lavoy, Co-advisor

Frank M. Teti, Chairman
Department of National Security Affairs

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LIST OF ABBREVIATIONS

ACDA	Arms Control and Disarmament Agency
BWC	Biological Weapons Convention
CALIOPE	Chemical Analysis by Laser Interrogation Of Proliferation Effluents
CFE	Conventional Forces in Europe (Treaty)
CIA	Central Intelligence Agency
CP	Counterproliferation
CW	Chemical weapons
CWC	Chemical Weapons Convention
DIA	Defense Intelligence Agency
DoE	Department of Energy
EIF	Entry Into Force
ERDEC	Edgewood Research, Development and Engineering Corporation
FTIR	Fourier Transform Infrared
HUMINT	Human intelligence
IR	Infrared
IR DIAL	Infrared Differential Absorption LIDAR
LIDAR	LIght Detection And Ranging
NPT	(Nuclear) Non-Proliferation Treaty
NTM	National Technical Means
OPCW	Organization for the Prohibition of Chemical Weapons
OSCC	Open Skies Consultative Committee
OSI	On-site inspection
OST	Open Skies Treaty
OTA	(Congressional) Office of Technology Assessment
UNSCOM	United Nations Special Committee (for Iraq)
WMD	Weapons of Mass Destruction

Air Sampling Sensors for the Open Skies Treaty?

EXECUTIVE SUMMARY

LT Greg D. Rowe, USN

On March 24, 1992, the Open Skies Treaty (OST) was signed by twenty-six states, including all NATO and former Warsaw Pact nations and four former Soviet Republics – Russia, Belarus, Georgia, and Ukraine. As of the end of 1995, all but the former Soviet republics have ratified this confidence-building treaty, allowing mutual overflights among all signatories to provide transparency of security actions within the regime. The OST provides for the use of photographic, video, infrared, and synthetic aperture radar (SAR) sensors during flight to monitor security-related activities in the state subject to an overflight. The treaty allows for additional sensors to be proposed, agreed upon, and added. One sensor type debated for initial inclusion in the sensor suite but not approved is that of air sampling sensors capable of environmental monitoring. Further, these may be used for detection of illicit chemical weapons (CW) production. Several different technologies exist which may be viable in this role for this sensor-symmetrical regime.

As of the end of 1995, over 150 states have acceded to the Chemical Weapons Convention (CWC), a multinational pact banning the production, storage, testing, and use of CW. The CWC is awaiting ratification of at least 65 of its signatories before it enters into force. The CWC is the most intrusive arms control treaty ever signed. Considering the myriad uses of chemicals in today's world, this intrusion is required to verify CWC compliance. Still, there are many conceivable noncompliance scenarios for states desiring chemical weapons.

This thesis addresses the question, "Would the incorporation of air sampling sensors into the OST sensor suite complement the verification of the CWC?" First,

technical issues are addressed. Chemical weapons attack the body in four different ways – blistering the skin or lungs, choking, disabling the blood's processing of oxygen, or paralysis of the nervous system. Precursors and product processes make these categories of CW overlap with many commercial products, making detection of CW production difficult and ambiguous. To detect noncompliance with the CWC, the Organization for the Prohibition of Chemical Weapons (OPCW) requires coordination with intelligence sources, including National Technical Means (NTM) and human intelligence (HUMINT). If air samplers were to be incorporated onto OST aircraft, their use would require targeting data and facility layout of suspect CW production sites.

Can we detect CW through airborne sampling? A model developed by Battelle Laboratories, one of roughly forty similar models, details CW detection in two noncompliance scenarios. Effluent emissions are studied for probable output levels. Two technologies have been identified as capable of detecting CW: laser-based systems and infrared (IR) systems. Both of these systems operate in the 8 - 12 micron range on the electro-magnetic spectrum. Parameters such as range, scan time, probability of error, and accuracy are described. Operational considerations such as cost, maturity, and technological limitations are reviewed. Both of these technologies are deemed capable of performing both an environmental monitoring role and CW detection mission. We know that there are technologies capable of detecting CW from an airborne platform at OST operating altitudes.

What are the political and legal hurdles between coordination of the OST and the CWC? The OST is a 27-member confidence-building measure, intended to raise the level of trust between its members. It has unrestricted territorial access, yet the resolution of its sensors are limited to building confidence without allowing extreme intrusion. The CWC is a 159-member verification treaty, with stringent reporting procedures, routine inspections, and provisions for challenge inspections if illicit activity is suspected by a party. It bans all but a few defensive activities related to CW. The

cross-treaty synergy of air samplers on OST hold much promise. CWC inspections would become more efficient and focused. Inspectors would be better prepared for inspections. Although the OST would become more intrusive, the CWC would become less intrusive through complementary air samplers.

Are these two treaties compatible from a philosophical and practical standpoint? Using OST for verification could change its confidence-building intent. The sensors for OST were thoroughly negotiated, and prospects for adding sensors before the treaty has entered into force are unlikely. The OST calls for unanimity in any of its amendments – achieving consensus may be extremely difficult on this issue. Uneven application of these measures between the incompatible memberships of the two treaties will be unacceptable to some. An overt, intra-treaty measure like this may force renegotiation of many aspects of each treaty before either enters into force.

What are the international political issues? Politically, the crossover between these treaties could be untenable. Each was negotiated with specific measures in mind, and with no particular compatibility or complementary role intended. Many in the industrial sector, both in the United States and abroad, have proprietary concerns and worry about industrial espionage from CWC verification procedures. Adding another means of intrusion would be unacceptable to them. This concern can be solved, though, through negotiations on which chemicals the technologies would search for, excluding any others that may be of proprietary concern. Still, there are concerns about sovereignty and rights to secrecy that stand as obstacles to the inclusion of air samplers on OST. Specifically in the United States, the treaty's inspection procedures may violate the search and seizure provisions of the Constitution's Fourth Amendment. The official U.S. position on this issue is classified, and although we do not actively pursue putting air samplers onto Open Skies aircraft, interagency discussion of this option is ongoing.

To summarize the findings of this research, the proposal to incorporate air sampling sensors into the OST sensor suite, either for environmental sensing or to

complement the CWC is not likely to come to fruition in the near future. There are technologies available to do this, and, given correct timing and intelligence coordination, there are detectable traces of illicit CW production. There are even many benefits to a complementary verification role of the OST to the CWC. However, intra-treaty issues, proprietary concerns, and political opposition present insurmountable hurdles in the near future. Once each pact has entered into force and inspection procedures become systematic and proven, there may be the potential to incorporate these sensors first as a means for environmental monitoring, and possibly to assist verifying the CWC.

ACKNOWLEDGEMENTS

The author would like to acknowledge the financial support of the Institute of National Security Studies (INSS) in Colorado Springs, Colorado, and especially the assistance of Lt Col Jeff Larsen, United States Air Force. INSS support allowed me to travel to Washington, D.C. in April 1995 to interview many experts on my thesis. I also gained valuable experience through participation in INSS's Research Conference, allowing me to present my thesis and receive feedback from military and arms control professionals.

The author would like to thank Professors Jim Wirtz and Peter Lavoy, my thesis advisors at the Naval Postgraduate School, for their continued support and guidance during my research and writing of this thesis. They righted me when my writing strayed and my prose became muddled.

The author would especially like to thank Dr. Joseph Leonelli of Battelle Memorial Institute in Columbus, Ohio. His technical guidance and corrections were invaluable not only to my research but to my education on air sampling sensors. Any errors made in the technical portion of this paper are the author's alone, despite Dr. Leonelli's valiant efforts by fax and e-mail.

Finally, this research would have never come to fruition if it were not for Donna Shank, wife and friend of the author. Ti amo!

I. INTRODUCTION

The most acute threat likely to be encountered by the United States in the future is that of weapons of mass destruction in the arsenals of its rivals, and even in the hands of terrorists. These weapons – nuclear, biological, and chemical – have a twofold purpose. First, militarily they act as force multipliers for outmanned armies, supplying both tactical and strategic advantages. They can kill people in mass numbers, soldiers or civilians, with reduced tactical risk to the employer of the weapon. They can turn the tide of a battle to an inferior force. They can also cause a different strategy to be adopted by an enemy force. Second, they have psychological effects on the enemy they are used against. They kill people in devastating ways – scorching flesh, attacking nervous or immune systems, or causing painful and slow deaths; survivors can suffer lasting disabilities.

Efforts have been made, especially since the end of the Cold War, to outlaw and eliminate these weapons. Cold War efforts to reduce nuclear weapons are continuing and are expanded through START and the indefinite extension of the Nuclear Non-Proliferation Treaty (NPT). Biological weapons, never having been used in a wartime scenario, are being outlawed by the Biological Weapons Convention (BWC). Chemical weapons were outlawed in 1925 by the Geneva Convention, with more stringent measures to be effected by the recently-signed Chemical Weapons Convention (CWC). At least twenty countries currently possess CW and means to produce them, and another ten are attempting to acquire CW and the technology for production.[1] This thesis focuses

[1] Anthony H. Cordesman, "One Half Cheer for the CWC: Putting the Chemical Weapons Convention into Military Perspective," ed. Brad Roberts, *Ratifying the Chemical Weapons Convention*, (Washington, D.C.: The Center for Strategic and International Studies, 1994), p 37; U.S. Congress, Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559 (Washington, D.C.: U.S. Government Printing Office, August 1993), p 14; correspondence from Joseph Leonelli, Battelle Memorial Institute, Columbus, Ohio, October 18, 1995.

on efforts to detect the illicit production of chemical weapons using existing treaties and intelligence measures.

The negotiations of the CWC included discussion of the use of aerial inspections to assist in verification of the convention. These measures were rejected when on-site inspections (OSIs) were deemed intrusive enough for the purposes of the treaty. The concept of aerial inspections to verify the CWC has a lot of merit though, and has been studied as a possibility.[2] Another treaty that involves overflights for security action confidence building, was signed in 1992 and is awaiting entry into force (EIF). This treaty is the Open Skies Treaty (OST), and during its negotiations, sensors for air sampling were discussed. These sensors were considered primarily for environmental monitoring, but also considered for detection of chemical weapons (CW) production. The OST already compliments to the Conventional Forces in Europe Treaty (CFE). The CFE is limited to west of the Ural Mountains, whereas the OST allows uninhibited territorial access. The OST also is an intelligence supplement for many states, especially helping those with no National Technical Means (NTM), such as satellites or reconnaissance aircraft.

The research presented here tries to answer the question, "Could air sampling sensors incorporated into the OST sensor suite compliment CWC verification?" The argument separates into three topical areas: technical issues, intra-treaty political and legal issues, and international political issues.

The technical chapters focus on procurement, production, and military use of chemical weapons, and how to detect production. Chapter II examines chemical weapons, their precursors with commercial utility, and dual-use production processes. The building blocks for chemical weapons have many commercial uses, the feed chemicals and production information are widely available, and CWs are relatively cheap

[2] This is the theme of Amy Smithson and Michael Krepon *"Strengthening the Chemical Weapons Convention Through Aerial Inspections,"* Occasional paper no. 4 (Washington, D.C.: The Henry L. Stimson Center, 1991).

when compared to other WMD. Chapter III looks at intelligence efforts, both NTM and human intelligence, to detect CW production, as well as counter-intelligence efforts to conceal production. The use of air sampling sensors requires accurate targeting information on the location of production sites and operating times, necessitating intelligence support. Chapter IV demonstrates two models of CW production in a CWC noncompliance scenario. Chapter V reviews two technologies available for airborne CW production detection: laser-based optical sensors and Fourier transform infrared sensors. Details of operating range, scan time, probability of error, accuracy, limitations, and cost are revealed.

The intra-treaty chapters examine the relationship of the Open Skies Treaty and the Chemical Weapons Convention. Background, membership, and intent of each treaty are outlined. Finally, a look at arguments are presented both for and against incorporating air samplers into the OST for this purpose.

The international politics chapter reviews diplomatic obstacles and reservations on this proposal. In conclusion, summaries of the arguments for and against the incorporation of air samplers into the OST sensor suite to verify the CWC are reviewed, leading to the realization that this proposal, although not without its merits, is not something that will happen in the near future.

II. CHEMICAL WEAPONS

This chapter describes chemical weapons. Chemical weapons are an attractive option for a state seeking a weapon of mass destruction because of their cost relative to nuclear weapons, and ease of production. Procurement of CW is facilitated because of the overlapping commercial utility of the processes and building blocks for industrial chemicals. These production advantages are discussed first. Second, the four categories of CW are outlined. Dual uses of CW precursors and processes are reviewed. Finally, the potential for multi-component, combinable chemical weapons is discussed.

The procurement and the production of chemical weapons have many advantages over nuclear weapons. The feed chemicals used for production of CW have myriad commercial uses such as production of pesticides, pharmaceuticals, fertilizers, and even pen ink. Much of the equipment and processes used are used in commercial processes. The Congressional Office of Technology Assessment (OTA) states: "The technology used to produce chemical weapons is much harder to identify unambiguously as weapons-related than is that for nuclear materials production technology, and relevant know-how is much more widely available."[3]

Developed countries with many diverse commercial chemical production plants and legitimate industries could hide illicit production. Underdeveloped countries would attract more attention in their procurement processes through the types of raw materials they purchase or extract domestically. The types of plant facilities they import and assemble, such as high-quality, non-corrosive piping and valves or sophisticated filtration systems might also attract attention. Still, supply side counter proliferation is extremely difficult due to the dual uses of chemicals and equipment. As Julian Perry Robinson

[3] U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, D.C.: U.S. Government Printing Office, December 1993) p. 6.

writes in the book *Chemical Weapons and Missile Proliferation*, "The dual use nature of many chemical technologies has made chemical weapons proliferation 'an unfortunate side effect of a process that is otherwise beneficial and anyway impossible to stop: the diffusion of competence in chemistry and chemical technology from the rich to the poor parts of the world.'"[4] The increasing availability of chemical production facilities and chemical expertise, and the common usage of most basic chemicals for purposes such as fertilizers, pesticides and pharmaceuticals have made the building blocks for simple chemical weapons production to most nations in the world. Contrasted with the highly technical facilities, know-how and rare materials such as plutonium and uranium variants needed for the manufacturing of a nuclear arsenal, chemical weapons are a more attainable goal for nations desiring weapons of mass destruction.

Complicating detection may be some states' disregard for basic safety measures when constructing a CW production facility. The Iraq facilities inspected by UNSCOM lacked many common safety provisions for workers. Processes normally requiring non-corrosive piping used available piping. The Iraqis overcame this by merely replacing corroded pipes with new ones. If specialized supplies were cut off by Western European nations, many were reverse engineered to maintain stocks.[5] Similarly, lax safeguards have been documented from CW facilities in the former Soviet Union. These standards affected many of the workers long term health.[6] These practices make detection from the supply side difficult.

The OTA states: "Although hundreds of thousands of toxic chemicals have been examined over the years for their military potential, only about 60 have been used in

[4]OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 19. The inner quote is from Julian Perry Robinson, "Chemical Weapons Proliferation: The Problem in Perspective," ed., Trevor Findlay, *Chemical Weapons and Missile Proliferation* (Boulder, Colo: Lynne Rienner, 1991), p. 26.

[5]Phone conversation with Kathleen Bailey, Lawrence Livermore National Laboratories, September 21, 1995.

[6] "Russian Experts Say Many Died Making Chemical Weapons," *New York Times*, December 24, 1993, p A8:1.

warfare or stockpiled in quantity as chemical weapons."[7] There are four basic categories of chemical weapons, each with different toxicity, volatility, battlefield persistence, and stability. These characteristics influence ease of procurement and production, intended battlefield use, and storage longevity. The Chemical Weapons Convention separates chemical agents into three schedules. Schedule 1 lists twelve super toxic chemicals that are key to nerve and blister agents and have no known commercial value. Schedule 2 has fourteen chemicals characterized as very toxic, not widely used in industry, and of significant risk for use in CW production. Schedule 3 lists seventeen toxic precursors and chemicals that are frequently used in industry, but still pose a risk because they have been used in chemical weapons. The schedules allow increasing quantities of chemicals to be produced and stored as the toxicity decreases and commercial applications increase.[8] These schedules are covered in more detail in Chapter VI.

The four categories of chemical weapons are:

1. *Blister agents (vesicants).* These agents cause external blistering. If inhaled they can also cause lung blisters, which can drown victims. Examples of these chemicals are sulfur mustard (mustard gas) and lewisite. These have low toxicity, are easy to produce and have high persistence on the battlefield. Mustard gas accounted for many casualties during World War I, but a low percentage of those casualties resulted in fatalities. Component chemicals such as thiodiglycol used in sulfur mustard are used for plastics, ink, pesticides and paper. Some of these are included on Schedule 1 of the CWC as super toxic chemicals.

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[7]OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 18. This was quoted from World Health Organization, *Health Aspects of Chemical and Biological Weapons: Report of a WHO Group of Consultants* (Geneva, Switzerland: WHO, 1970), p. 23.
[8] Smithson, ed., *The Chemical Weapons Convention Handbook* (Washington, D.C.: Henry L. Stimson Center, September 1993) pp 4 & 7.

2. *Choking agents.* These agents irritate and inflame bronchial tubes and lungs and may cause asphyxiation. Examples of these weapons are phosgene and chlorine. Like blister agents, these also are fairly easy to produce, though not as toxic as other chemical agents. Phosgene and chlorine have many commercial applications in combination with other chemicals, such as fertilizers, and are listed on Schedule 3. These were also used in World War I.

3. *Blood agents.* These block oxygen circulation in the body and starve the tissues of oxygen. Examples of these agents are hydrogen cyanide and cyanogen chloride. Blood agents have a fairly high toxicity level but are more complex to produce and have many commercial applications, making their production ambiguous.

4. *Nerve agents.* These chemicals interfere with transmission of nerve impulses, causing convulsions and death by respiratory paralysis. Examples of these weapons are tabun (GA), sarin (GB), and VX. Nerve agents are listed under Schedule 1 of the CWC as super toxic chemicals. These are from the same chemical group as pesticides, organophosphorus chemicals, but are 100 to 1,000 times more toxic than pesticides.[9] Sarin was the nerve gas used in the March 20, 1995 Tokyo subway terrorist attack. Many of the basic feedstock chemicals used in the production of nerve agents (e.g., ammonia, ethanol, isopropanol, sodium cyanide, yellow phosphorus, sulfur monochloride, hydrogen fluoride, and sulfur) are commodity chemicals that are used in commercial industry at the level of millions of tons per year. As a result they are impossible to control.[10]

Nerve agents are hard to manufacture and store, due to their high toxicity. They must be produced under tightly controlled conditions.[11] Challenges in producing nerve

[9]Alan R. Pittaway, "The Difficulty of Converting Pesticide Plants to CW Nerve Agent Manufacture," Task IV, Technical Report No. 7 (Kansas City: Midwest Research Institute, Feb. 20, 1970), p. 1.
[10]OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 29.
[11]This entire section was based on information derived from, OTA, *Technologies Underlying Weapons of Mass Destruction*; and Smithson, ed., *The Chemical Weapons Convention Handbook*.

agents include the cyanation reaction (entailing the containment of a highly toxic gas), the alkylation step (requiring the use of high temperatures and highly corrosive byproducts), meticulous temperature controls, intermediaries which act explosively with water forcing the use of heat exchangers, and difficult distillation processes (ensuring longer shelf life). None of these processes, however, is uncommon in normal commercial applications. They may require only minimal conversion of equipment to produce nerve agents.

Chemical weapons may be either unitary or binary in design. Unitary weapons are toxic after production and ready to launch, but can be less stable and may have a shorter shelf life. Binary weapons have two separate component chemicals and need to be mixed either just prior to launch for toxicity or, with advanced munitions, may be designed to combine in flight for toxicity. Binary precursors are listed under Schedule 2 of the CWC. As the OTA states, the problem is then presented of mixing binary weapons on the battlefield or at the launch site, or "entail[ing] the considerable engineering challenges, both to accommodate the two components in a ballistically sound package and to effect the necessary chemical reaction during the flight of the shell or bomb."[12] Some nerve agents, such as sarin and VX, can be produced as binary weapons, reducing the complications in producing component chemicals yet still requiring complex weaponeering. Chemical warheads are only a portion of a weapon, and delivery systems are needed.

Chemical weapons can also be produced as tertiary or quadranary weapons using three or four component chemicals and mixing them just before employment.[13] Each of these chemicals may be itself non-toxic and have multiple commercial uses, but when combined, they make a deadly warhead. The benefits of this type of weapon are obvious. A separated weapon can be safely handled by workers and weaponeers alike, and can be composed of CWC Schedules 2 and 3 chemicals, allowing mass quantities to be

[12]OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 34.
[13] Phone conversation with Bailey, September 21, 1995.

produced. Again, depending on the sophistication of the weaponeering, these weapons can be launched as toxic warheads or possibly combined inflight. In light of the specific chemistry, this could be a violation of the spirit if not the letter of the CWC, as long as a covert weaponeering capability is maintained. Dr. Kathleen Bailey of the Lawrence Livermore National Laboratory intimated that the Russians, although having foresworn a CW arsenal, maintain a robust CW warhead weaponeering capability.[14]

In the detection process of CW, there are two types of effluents released from a chemical plant: controlled smokestack emissions and "fugitive" emissions.[15] Smokestack emissions are planned emissions from the production facility and would be filtered. Fugitive emissions are stray emissions in either production, testing or storage and would be unintended. Chemical weapons production is more likely to be detected through the unintended or accidental release of effluents since they would not be filtered or disguised and probably would be in greater concentration than planned emissions. However, essentially perfect timing would be required to catch fugitive emissions, so considerations for this thesis will consider only the level of planned emissions.

A major factor in the possible detection of chemical weapons production, testing or storage is the level of sophistication of the facilities; ideally, no extraneous emissions will escape in any of these processes. This is obviously something any producing state should be wary of – the potential poisoning of their chemists or people living nearby through poor controls of production processes. This is not always the case, as witnessed in Iraq and the former Soviet Union. It is virtually impossible to prevent some chemical constituents from being released, unless extreme filtration and disposal precautions are taken. In countries that are less technically advanced, there may be a greater possibility for fugitive emissions of agents, chemical weapons precursors, or even their byproducts, thereby allowing for effective sampling.

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[14] Ibid.

[15] OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 65.

Chemical weapons are cheap, easy and ambiguous to produce, and highly effective on the battlefield. The component chemicals and processes required to develop a CW capability are widely available and already used for many commercial purposes. Depending on the sophistication of a CW program, these weapons can be safely handled and weaponeered. Further, they can be produced in quantities below detection levels from monitoring of supply chemicals and equipment, yet yield enough for effective arsenals.

III. DETECTION AND DECEPTION

This chapter describes the efforts needed to detect an illicit chemical weapons program, and the measures taken by states trying to conceal their production and arsenals. The United States has many assets at its disposal to counter the spread of weapons of mass destruction, from satellites and human intelligence efforts, to CWC verification measures. The benefits and limitations of NTM and human intelligence detecting covert CW production are explained in this chapter. Eight potential noncompliance scenarios for the CWC are also identified. Finally, other factors for consideration when searching for CW production, such as geography, industrial base, military strategies, and external threats, are reviewed.

Solving the chemical weapons counterproliferation puzzle requires several initiatives. The United States hopes to dissuade other states politically and diplomatically from acquiring chemical weapons through security guarantees, punitive actions like economic sanctions, and at worst, ostracism for departing international norms. Further, the Chemical Weapons Convention places obstacles in the path of states that desire to acquire these weapons through its reporting procedures and inspection regime.

Despite these "soft" efforts, the United States still must use every means available to discourage and counter proliferation of CW, including an aggressive intelligence effort both through National Technical Means (NTM) and human intelligence (HUMINT) programs. To be able to use air sampling sensors to detect CW production, targeting information on suspect sites is desired. Coordination of intelligence assets to detect CW production is required.

A. INTELLIGENCE COLLECTION

As seen in Chapter II, the detection process for clandestine production of illegal CW is complex due to legitimate commercial uses and production procedures which can cover for illegal activities. Positive detection usually cannot be determined through any single method but rather a through a synthesis of remote sampling, on-site inspections, reporting procedures, and intelligence collection. The level of internal control, secrecy, emissions filtering, and safety procedures installed by a state attempting to produce these weapons illegally affect the ability of inspecting parties to detect them. The active cooperation of a state in a verification regime, such as the still-unratified Chemical Weapons Convention, could assist in detection of illegal activity, or at least narrowing the focus of a search for illegal activity. Cooperation may even come from states trying to acquire CW, thereby concealing their attempts to develop a program. James Woolsey, the head of the Central Intelligence Agency (CIA), told Congress in June 1994 that American intelligence was not sure that it would be able to detect all violations of the CWC, yet he still urged ratification to assist deterring proliferation.[16] Even with cooperation within the CWC to detect CW production, U.S. reliance falls onto NTM, such as U2 or satellite products, and HUMINT, through observation and insider contacts.

NTM are very capable and extremely accurate in what they collect – information, but not analyzed intelligence. Derivatives of this information include parameters and activities. Parameters include information like the external layout, physical dimensions, and operating temperatures of a facility. Activities include type of equipment brought into a plant, operating hours, and routines of a given organization. The information collected must be analyzed and interpreted, which leaves room for variations in analysis. Another limitation of NTM products is their collection window, which is generally known through satellites' predictable orbits or possible detection of U2 overflights.

[16] Michael R. Gordon, "C.I.A. Backs Arms Treaty On Chemicals," *New York Times*, June 21, 1994, A9:1.

Closely guarded activities can be protected from collection attempts during vulnerability windows. Information that cannot be collected through NTM include identifying the intended use of the equipment brought into a plant, or whom troops are training to engage.

Satellites or reconnaissance aircraft may use several sensors to detect possible CW production. The most obvious is photographic equipment. Infrared sensors may detect extremely high temperatures associated with alkylation processes for nerve agents. They may also detect unusual operating hours, such as nighttime operations not normally associated with the plant's schedule. Continuous operations may be the norm for some plants which operate on a batch to batch basis, disallowing interruption because of shift changes. Detected operations may be checked against CWC reporting procedures to verify plant operations and outputs. Some of these operations may also be monitored intermittently by Open Skies overflights.

The activities and output of a particular chemical production plant, one of hundreds or maybe thousands, in a given country, can remain totally ambiguous to analysts of NTM information. To try to identify illegal activity, the focus of NTM must be narrowed to "suspect" sites, chemical production or storage facilities which have the capability for CW production and are presumed through monitoring to be producing CW. This is where HUMINT becomes effective. HUMINT can monitor firsthand activities and can establish contact with production, storage, or testing insiders. All the technical means of collection, NTM and military operational systems, need to be augmented by human intelligence, which helps decipher nuances in action, subtleties in meaning and ultimately, intentions.

Human intelligence is manifest in many forms. An agent can work his or her way into a country's infrastructure over a long period of time, becoming a "mole." An agent working in a country can establish contacts, either in political and diplomatic circles or among low-level workers within industries that may be suspected of clandestine activity.

The level at which an agent establishes contacts relates directly to the position he or she holds within a country, either as a diplomat or attache, a wealthy businessman, or just an expatriate working in country. In the case of detecting a CW program, a low level contact may not know enough about a program to reveal it, whereas a higher level contact may know the desire of a state to pursue a CW arsenal, and through the state's intentions, reveal the program. A high level agent should make contacts in the diplomatic, economic, and military arenas, or these areas can be covered by several agents if required. In concert, HUMINT contacts can expose both the intent to produce CW and the locations capable of and suspected of production.

Intelligence sources also have some weaknesses. Angelo Codevilla observes an interesting point related to analysis and its reliance on technical means of collection: "Because modern technology is a versatile servant of the human will, the superficial glances at...technology that the U.S. technical intelligence is capable of providing will raise more questions than they answer, and invite intelligence officers to answer them with their own assumptions."[17] Caveats are included with HUMINT as well. By using intelligence generated solely through HUMINT, heavy reliance can be placed on a single, uncomplemented, unsupported source. The potential is great for bias, even if several HUMINT sources are cross-referenced. HUMINT can be unpredictable and asystematic. The reliability of the agent or agents and their sources must be considered when using HUMINT, as well as their historic effectiveness and experience in the region being examined.

A combination of satellite products and HUMINT identified the CW production and storage facility in Rabta, Libya in 1988.[18] Reconnaissance photographs indicated an unusually large pharmaceutical plant at Rabta, with multiple barbed wire fences, sand revetments, and extraordinarily large effluent filtration systems. HUMINT agents sought information from foreign technicians and construction workers who worked on the Rabta

17 Angelo Codevilla, *Informing Statecraft* (New York: The Free Press, 1992), p. 128.
18 OTA, *Technologies Underlying Weapons of Mass Destruction*, pp. 42-44.

plant about plant layout, design, and capabilities. Finally, agents intercepted frantic calls from Libyan foremen to German plant designers asking about emergency clean-up of a spill and satellite imagery revealed a dead pack of wild dogs downwind of the plant, unscavenged (indicating the presence of poisons). These actions helped confirm the production of CW at Rabta. Although developing countries like Libya are more likely to draw attention with the construction of a new plant, lessons from the intelligence coordination of this case may assist in solving further cases.

There are some clues to look for in the detection of a clandestine CW program. Production plants may be isolated, or they may be masked within a commercial plant in an industrial area with similar production processes. Isolated plants, such as the Rabta facility, would tend to be remote and difficult to locate, with unusually strong security measures. Precautions would need to be taken by technicians and chemists in transiting to and from the plant to avoid detection, or to ensure that the cover of the plant was maintained, like the pharmaceutical cover used for Rabta. Shipments to and from an isolated plant may occur at night or during satellite vulnerability windows to guard origins and destinations, if possible. This is a more likely scenario for a lesser developed state, keeping these dangerous activities away from civilian populations, possibly more to keep them isolated and secure than for safety considerations.

Dual usage plants, with commercial uses masking covert operations, would need tight security for the covert portion of the plant and safety precautions. This type of operation would not necessarily take a large facility. Nor would it take a dedicated production line, but production of CW could be accomplished on a batch-to-batch basis with legitimate production between cycles. Kathleen Bailey of the Lawrence Livermore National Laboratory states, "A dedicated chemical agent facility for producing 100 tons of agent per year may be as small as 40 by 40 feet, with some portion being 40 feet high. Given that there are currently no technical means for locating undeclared production sites, finding one would depend on obtaining accurate intelligence information from a

human source."[19] It is easy to mask the dual use nature of many precursor chemicals. Further, calculations trying to gauge facility output from material input, known processes, and expected waste, are deemed fruitless. As the OTA notes, "Materials-balance calculations cannot provide a reliable indicator that precursor chemicals are being diverted to CW agent production."[20]

Signs of storage and testing may be monitored to indicate an active CW program. Indicators of storage are unusually stringent security measures and possibly the inflow of specially equipped vehicles for transferring the CW. Signs of testing of chemical munitions include dead, unscavenged animals, possibly tied up or pent-up at increasing intervals from a potential detonation site. Any indication of concentric circles, grids or testing for spread patterns may also identify testing (these would need to be collected from reconnaissance imagery). Testing, however, is not necessarily a requirement for conducting a CW program, especially if a country has a long history of CW manufacturing or has received good information about CW production or blueprints for manufacturing knowhow.

The other piece of the CW puzzle is weaponeering. Indicators of short-range ballistic missile capability or other known chemical agent carriers, such as air burst mortars or rocket-propelled grenades, may be a sign of a CW program. The capability to deliver CW does not alone indicate a program, but it is an integral part of a CW arsenal.

Any single method or "cookbook" approach to detection of a clandestine CW program can be defeated by counterintelligence efforts on the part of the violating state, fully expecting efforts to detect and defeat them.

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[19] Bailey, "Why the Chemical Weapons Convention Should Not Be Ratified," in ed., Brad Roberts, *Ratifying the Chemical Weapons Convention* (Washington, D.C.: Center for Strategic and International Studies, 1994) p. 52.

[20] OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 39.

B. CWC NONCOMPLIANCE SCENARIOS

In a critique of the CWC, Bailey has identified eight different noncompliance scenarios states may favor to acquire CW or a CW capability.[21] Of these scenarios, four are detectable by NTM, three by air sampling sensors, and only three might be detectable through CWC verification. All eight scenarios could be detected with a robust HUMINT program. Some could be detected at the worker level, but all could be detected through a high level agent aware of policy aspirations.

The first scenario, the use of CW, would be detectable through any of the four mentioned methods. The use of CW could occur during a test, in a covert scenario, or as an act of war. If used on troops or even populations, detection would be reported by the attacked state or group (such as Iraqi use against the Kurds during the late 1980s). Testing could be detected using either HUMINT contacts, NTM to view damage, an overflight to view damage and possibly detect CW (depending on the timing), and through CWC procedures.

The second scenario, failure to destroy declared CW capabilities, is verifiable through the CWC or NTM. Air samplers would be ineffective at detecting stored chemicals unless there were an accidental leak of fugitive effluents. HUMINT could be used at a high level to detect intentions to retain CW arsenals.

The third scenario, illicit production of CW in a declared facility, is detectable using CWC verification procedures if in-depth inspections occur, such as dismantling equipment to test residues. Amy Smithson believes this can be an effective method of detection: "...[T]elltale signs of cheating are likely to be left behind in the rush to cover up prohibited activities before the arrival of inspectors, All traces of chemical weapons production can be very difficult to hide, especially if state-of-the-art emission controls were not used at the site....The possibility of incurring challenge inspections may also

[21] Bailey, "Why the Chemical Weapons Convention Should Not Be Ratified," p. 53.

deter states from attempting to establish a covert weapons program."[22] Given proper timing and targeting, this method of cheating could be detected by air sampling of the effluents of a declared facility. NTM would be ineffective at initial detection of this type of noncompliance.

The last scenario detectable by non-HUMINT means is clandestine production in an undeclared facility. Even for this fourth scenario to be detected by NTM or air samplers, a HUMINT tipoff would be required. Indicators include remote, heavily guarded facilities, requisite feed chemicals and production processes, and exports to places such as munitions factories. For air samplers, effluent testing and fortuitous timing are needed. A clandestine plant could also be revealed through HUMINT from specific workers or foreign chemists or engineers. Eavesdropping was used to help determine that the Rabta facility was producing more than its purported pharmaceuticals. This intercepted the frantic phone conversation to facility producers in Germany after a spill occurred, leading to U.S. charges of CW production.[23]

Bailey's fifth scenario, diversion of chemicals for agents from a declared facility, would either need HUMINT from a "worker bee" within the suspect facility, or a high official who knew of the diversion program. This type of noncompliance is working around the supply side of the CW puzzle, which is very difficult to detect. Chemicals siphoned from a declared facility would probably be components of a binary, trinary, or greater part CW warhead because precursors to produce a CW agent would still need processing at some facility. Combinable components would need no further processing.

To detect the sixth noncompliance scenario, keeping secret stockpiles of weapons, agents, or precursors, would require a well-placed worker, or, again, a high official. Any means of detection beyond HUMINT would be improbable.

Detection of the seventh scenario, production of non-classical agents in either a declared or undeclared facility would require in-depth knowledge of chemical processes,

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[22] Smithson, "The Chemical Weapons Convention Handbook," p. 34.
[23] OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 42.

or a high placed official with knowledge of the production. Bailey discovered "revelations of a new Russian binary chemical agent, two components of which reportedly are not on the CWC schedules of controlled compounds.[24] Thus, there may be chemical agents that do not use scheduled chemicals, so inspectors will not even be able to look for them."[25] Under the CWC schedules, only known CW agents and precursors are listed. Other detection methods would again be fruitless, considering inspectors would not know what to search for.

The eighth scenario, the transfer or covert receipt of weapons, materials, or technology, could only realistically be detected through HUMINT. Coordination with NTM to track shipments and activities could help in this case, but HUMINT initiative would be required. CWC procedures are not broad enough to detect this. Air samplers also would be ineffective in detecting this noncompliance.

C. OTHER FACTORS TO CONSIDER

Solid and liquid disposal must be closely monitored. There are CWC provisions for effluent sampling during an OSI, but only in a restricted area and intermittent basis. Extra chemicals may be added to the residuals, or an ionization process performed, to change the residuals and make CW production undetectable or more ambiguous. Underground or remote disposal of degradation products through pipelines are an option. The presence of tanker trucks associated with the movement of hazardous chemicals would need to coincide with the presumed use of the plant. Trucks moving highly toxic chemicals like those used for CW would be readily identifiable. Decoy steel drums and

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[24] Bailey, "Why the Chemical Weapons Convention Should Not Be Ratified," p. 54. From Bailey's notes, this new CW agent, purportedly five to eight times more toxic that the most deadly form of VX nerve gas, was developed after the Soviet Union declared unilaterally in 1987 that it would cease development and producction of CW agents. Also as reported in the *New York Times*, January 28, 1994, A5:1.

[25] Ibid., p. 54. Oleg Vishniakov interview with Vil Mirzianov and Lev Fedorov in *Novve vremia*, as translated in Joint Publications Reaserch Service-Arms Control-92-033, November 14, 1992, p. 45. Mirzianov was later arrested by Russia for his revelations about the new CW agent.

other packing material normally associated with commercial chemicals may be located at a facility. "Normal" operations must be considered – if transportation from the plant occurs only at night or always under guard, that may be cause for suspicion of CW production.

Effluent monitoring may be done by NTM through coordination with weather modeling and detection of "biomarkers." Biomarkers are signs of abnormal ecological and biological patterns downwind or downstream from a suspect site. Prevailing winds and weather modeling for rain patterns can help determine the origin of dangerous chemicals. A common example is acid rain, not from CW production, of course, but from other toxic chemicals. The case of Volsk, Russia[26] is a good example regarding CW. Farmers reported cucumbers and grapes shriveling on their vines, cows were producing sour milk, and trees were noticeably drying out. All of this was attributed to unsafe destruction of the CW arsenal located at Shikhany, Russia's largest CW plant. Biomarkers need not be as severe as in Volsk to arouse suspicion about illicit activites at a given facility. Photographic details or surveillance of the ecosystem surrounding suspected chemical weapons production, testing or storage sites can be very revealing. The absence or withering of most vegetation and animals in a given area may indicate concentrations of poisonous emissions which prevent them from living in that area.

Trade-offs in production efficiency may need to be made to conceal a CW program. To reduce recognition of CW production, simplicity may need to be sacrificed for a more complex and multi-step production pathway. This also may slow the material-to-munition process considerably, but if no conflict is imminent, this may not be a factor in plant design. Tight safety and compartmentalization requirements may impede production and testing. Simple, undistilled CW products have a short shelf life: the long term stockpiling of an arsenal may require more intricate and dangerous distilling processes. Any reliance on imported materials may greatly affect a CW program,

[26] Judith Ingram, "Cribs Provide a Deadly Litmus Paper," *New York Times*, May 21, 1994, p. A4:1.

causing the use of diverse suppliers and different import methods, decreasing efficiency of the processes. Recall the Chapter II comments about Iraq's lax safety standards. The precautions taken to avoid detection of CW production must be balanced against urgency for the chemical weapons and expected use.

For a given country, many factors both for capability and intent must be examined to counter the proliferation of CW. These include economic, scientific, military, security, and meteorological issues. How developed is the industrial base of the country? What types of industry does it have and what type of commodities does it produce? What chemicals does it import or produce indigenously? A more developed country may more easily mask a CW program within its industrial infrastructure without garnering attention. If it already imports or indigenously produces chemicals used for CW, it would draw less attention to diversion. Similarly, if it has facilities that have parallel processes for producing CW, it may not need to import more equipment to begin or continue a CW program. These economic factors may reveal at least the capacity and capability to produce CW agents.

Does this country have the indigenous scientific and educational capabilities to produce the chemists, scientists, and technicians for a CW capability? If not, the importation of people with these particular talents may draw attention to their capability, as did the Rabta facility in Libya. There are ongoing programs to track the careers of scientists, chemists and engineers formerly employed by the Soviet military, wary that they may again ply their trades for the highest bidder, or relative to Russia, any bidder.

Does the military of the country in question have the capability to handle CW? Does its arsenal include weapons capable of carrying CW warheads, such as the SCUD or battlefield mortars? Does the military train to fight against CW? The donning of chemical, biological and nuclear retardant gear in training may indicate the ability to handle such materials and the willingness to use them on the battlefield, knowing troops are prepared to do so. What is the military doctrine of the country in question? Two

generations of Eastern European armies trained under Soviet tutelage, and may retain the capability and antipathy to use WMD. Does the army expect to use mass force against mass force, roving platoons against guerrillas, or seizure and possibly terror tactics against civilians? Is the army so small that force multipliers would be required against an invading army? Do they expect positional or mobile warfare?

Where is the country located and what does it feel are its greatest threats? If its threats seem overwhelming, would it consider WMD as a force multiplier and deterrent against potential enemies? Again, the former Warsaw Pact nations may feel they are threatened by growing Russian nationalism, or, as in the case of the Balkans, any xenophobic ethnic group. Middle East security retains its precarious balance because the Arab nations know Israel has a nuclear capability, and they refuse to accede to the CWC, veiling their desire to keep a CW capability.

Finally, in considering detection by others and safety for its people, what type of climate does the country have? An arid region need not worry about contaminating water supplies as much as a nation with high precipitation, where effluent traces of deadly CW may be drawn into the water supply, much like acid rain. In a rainy country, it may be more likely to conceal a CW production facility within an industrial area and use redundant filtration systems to avoid pollution. An isolated facility may draw more attention through biomarkers – signs high pollution. An arid climate, like Libya's or Iraq's, may be more conducive to remote CW production without drawing attention. A state with high precipitation must consider water flows and potable water for its people for CW production.

The nature of chemical weapons is such that almost any state can manufacture them. With the capabilities present, does the state in question have the intent to produce and arm itself with a force-multiplier like CW? This is a question that must be answered on a state to state basis.

Cooperative human intelligence is a good source of information, tempered by the possibility of counterintelligence and cross-referenced with other indications like NTM. The Rabta case demonstrates the use of technicians and foreign workers to gain intelligence about a facility. Employees may be indigenous and tightly screened for their loyalty, or the state may require foreign expertise. There is the potential to include low-level workers, such as truck drivers or loaders in a HUMINT program to test their blood or urine for chemicals that they themselves may not know they are moving. This could be a cooperative effort, or possibly a staged accident or incident could cause a blood sample to be required of an unsuspecting individual. The targeting of suspect sites through intelligence or CWC on-site inspections is a prerequisite for the use of air samplers for confirmation or detection.

IV. DETECTABLE EFFLUENTS

Since their use in the First World War and their subsequent ban in the 1925 Geneva Protocol, chemical weapons have been considered illegal, immoral and inhumane by the world community. But CWs are considered by many to be a force multiplier and are still produced today by some nations, as recent inspections in Iraq have revealed. There are many different ways that a state may cheat on the CWC provisions, or at least against international norms until the CWC enters into force.

The most likely noncompliance scenario involves the conversion of an existing chemical manufacturing plant to produce CW. This noncompliance would be made more opaque by the cheating state if this plant were to be located within an industrial region, allowing emissions to be masked by effluents from nearby legal chemical industrial plants, creating background "noise" that limits verification.

A second scenario would be similar to what occurred in Rabta, Libya during the 1980s, culminating with the U.S. State Department's September 1988 statement that it believed that Libya had established a CW production capability and was on the verge of full-scale production.[27] The Rabta facility is located in a remote, desert location with tight security, under the auspices of a pharmaceutical plant. These two scenarios were modeled for detectable chemical emissions in a report done for the Defense Nuclear Agency.[28]

The paper, published by Battelle Memorial Institute of Columbus, Ohio, assessed two different noncompliance scenarios for CW production and how they related to the capabilities of stand-off remote sensing technology. These production models are two of

[27] David B. Ottaway, "Behind the New Battle With Libya," *The Washington Post*, January 8, 1989, p. C4. As referenced in U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, p. 43.

[28] Joseph Leonelli and B. Thomas Smith, "White Paper on Analysis of Stack Emission Signatures from Chemical Agent Production Sites" (Columbus, Ohio: Battelle Memorial Institute, May, 1993). This chapter is based on this study.

approximately 40 developed by various government agencies and contractor organizations. There is no consensus on the "best" model for predicting detectable effluent chemicals. The two scenarios were developed to determine whether in the process of producing a CW agent, precursors, degradation products, or CW itself could be detected. Parameters of emission rate, stack gas exit velocity, stack dimensions, and configuration of the stacks were modeled. These were used to determine first order concentration estimates of the source strength of the stack emissions, and to conduct limited performance analysis of remote sensing techniques.

The noncompliance scenarios assumed the production facility was operating 24 hours a day, seven days a week and that a detectable plume was carried downwind at the rate of three meters per second, detected after ten seconds (therefore, a range of 30 meters from the smokestack). The standard measurement unit was average concentration pathlength product (CL). The formula for this is:

$$CL = \text{concentration } (mg/m^3) \times \text{pathlength } (30m), \text{ units being } mg/m^2$$

The first noncompliance scenario was production of GB (sarin) within a pesticide plant, capable of producing 100 tons of agent in one week. Design for this plant was assumed to have a stack one meter in diameter and a gas exit velocity of 18 meters per second (m/s). The model accounted for the emission rates of GB, DC (isopropyl alcohol), DMMP, DF, and DIMP (with GB, DC, and DF modeled both for scrubbed and unscrubbed emissions) in the effluent plume. All of these chemical constituents are expected to be emitted in the production of sarin.

The second noncompliance scenario was for the covert production of mustard gas (HD) at a remote military facility based in a desert location. This facility was supposedly capable of producing one ton per day for 100 days. Design for this facility was assumed to have a vent diameter of one decimeter and a gas exit velocity of 10.2 m/s. The model

accounted for the emission rates of HD, HCl, hydrogen sulfide, 2-Chloroethaniol, 2-Mercaptoethane, Dithane, Thioxane, and Ethylene Oxide in the effluent plume. All these chemical constituents are expected to be emitted in the production of mustard gas. This scenario assumes a much smaller outlet, a slower gas exit velocity, and therefore a decreased volume velocity of the effluent plume than the pesticide plant scenario. A smaller stack would probably be used for clandestine production.

Tables 1 and 2 provide the emission rate, concentration, and average concentration pathlength product, CL, for these two noncompliance scenarios for the chemicals examined. Sensitivity of laser-based and infrared technologies for detecting CL are presented later to confirm the viability of these technologies for confirmation of clandestine CW production. When using the tables, the important factor is the probable detectable emissions being fifty or more mg/m^2, which is listed in the last column. Those exceeding 50 are in bold print.

The assumptions and limitations of this model are important. The two noncompliance scenarios do consider planned emissions, that is, emissions normally in the effluent plume and expected by the producer to be released into the air. Planned emissions are more predictable than fugitive emissions. The scenarios assume continous operations, 24 hours a day, seven days a week, which may seem unrealistic. However, data from the Iraqi CW program indicates that they ran batch processes for 30 - 100 days continuously for twenty-four hours a day.[29] The OST allows for roughly one hundred hours notice before the commencement of an overflight, therefore allowing illicit CW production to shutdown to avoid detection. Nevertheless, this model does hold promise for future detection of noncompliance given optimum conditions.

[29] Correspondence with Joseph Leonelli, Battelle Memorial Institute, Columbus, Ohio, October 17, 1995.

Chemical	Emission rate (mg/s)	Concentration (mg/m^3)	CL (mg/m^2)
GB	24.99	1.77	**53.1**
GB unscrubbed	22680	1615.38	**48461.4**
DC	29.64	2.04	**61.2**
DC unscrubbed	17892	1274.36	**38230.8**
DMMP	2.23	.16	4.8
DF	21.74	1.55	46.5
DF unscrubbed	21735	1548.08	**46422.4**

Table 1 – Sarin Production

Stack area = $.78m^2$, Exit gas velocity = 18m/s, Volume velocity =$14.04m^3/s$

Chemical	Emission rate (m/s)	Concentration (mg/m^3)	CL (mg/m^2)
HD	.035	.438	13.14
HCl	460.5	5756.63	**172698.75**
H_2S	1.764	22.05	**661.5**
2-Chloroethanthiol	2.772	34.65	**1039.5**
2-Mercaptoethane	.033	.410	12.3
Ethylene Oxide	1.103	13.78	**413.4**
Dithane	.006	.074	2.22
Thioxane	.017	.213	6.38

Table 2 – Mustard Production

Stack area = $.0078m^2$, Gas exit velocity = 10.2m/s, Volume velocity = $.08m^3/s$

V. TECHNOLOGIES FOR AIRBORNE SAMPLING

Many technologies were considered by this research when trying to identify sensors capable of performing airborne detection of chemical weapons and their component chemicals. This chapter outlines two technologies: laser and infrared (IR) sensors. Each of these is currently under development by the United States for use in the spectral analysis and detection of chemical and biological agents.

Both of these sensors exploit the electro-magnetic spectrum to detect and identify chemical constituents. The most useful transparent spectral ranges of the atmosphere are: the visible (0.4 - 0.7μm), near infrared (0.7 - 1.5 μm), and infrared (3 - 5μm and 9 - 13μm [μm = one micrometer or micron, which is one-millionth of a meter {10^{-6}}]). Within these spectral regions, laser radiation is not appreciably attenuated except by the molecular species of interest, thus remote sensing over long ranges may be achieved. Chemical warfare agents have a rich infrared absorption and reflectance spectrum in the 9 - 11μm region due to the organo phosphorous (R-P = O) moiety present in the molecular structure of the compounds.[30] This is also true for these electro-magnetic spectra, regardless of sensor, so IR sensors will use these spectra as an effective detection range. Whereas lower exploitable spectral windows are useful for constituent identification, such as the 3 - 5 μm spectral region, this higher range, from 8 - 12μm, is sometimes referred to as the "fingerprint" region, with its higher frequencies and shorter wavelengths allowing better spectral clarity and accuracy.[31] In the lower spectral windows, longer wavelengths and lower frequencies do not allow the clarity required to discriminate chemical constituents from each other. This is why a interferogram, or IR

[30] Leonelli, "Dual-Use Applications of Laser Remote Sensing to the Military Battlefield and Environmental Monitoring," undated abstract, p. 1.
[31] Hughes Corporation, Proprietary Proposal for the RELIENTS System Consortium, prepared for the U.S. Army, undated 1994 paper, p. 2.

image, is generally less sharp than a photograph, which uses visible light at higher frequencies and shorter wavelengths.

Detection ranges can be extended by putting these sensors aboard aircraft. Aircraft experience less interference from water vapor, dust, smoke and other interferants which are in greater concentration lower to the ground. Detection horizontally through these interferants is inhibited, whereas vertical detection encounters only a fraction of these interferants and extends the range of the sensors. This may be especially true for IR sensors, which exploit temperature differentials. The background for a horizontal look at an effluent plume is mostly atmosphere or possibly hills or mountains; from a vertical aspect, there would usually be a greater temperature differential between the ground, which is the background, and the plume.

Laser remote sensing and infrared sensing are limited by operating range and atmospheric interference. Oxygen, carbon dioxide and water vapor absorb laser light in many regions of the electro-magnetic spectrum, making sensing in these regions ineffective. Other interferants include dust, IR smokes, snow, and rain, while phosphorous smoke is transparent in the 8 - 12μm range. To achieve detection at long distances, laser radiation must not be appreciably attenuated by the intervening atmosphere, with the greatest inhibitor being water vapor. The same is true for IR sensors. Conversely, very dry conditions may enhance sensitivity and increase detection ranges. This fact would give an advantage to detection in an arid, desert scenario, such as the second scenario considered by the model in Chapter IV. Many systems being tested operate from the ground, where atmospheric interference would be the greatest. An airborne detection system should have less atmospheric interference as it senses down vertically through the atmosphere, compared to detection horizontally through the atmosphere, as ground based systems do.[32]

[32] Leonelli, "Dual-Use Applications of Laser Remote Sensing to the Military Battlefield and Environmental Monitoring," p. 1.

A. LASER REMOTE SENSORS

Laser, which stands for Light Amplification by Stimulated Emission of Radiation, is coherent light of one color focused in one specific direction and emitted within a narrow frequency band. This differs from normal light, as from a light bulb, which is omnidirectional, multi-colored, and referred to as incoherent. The laser beam is directed into an effluent plume and using a technique known as LIDAR (LIght Detection And Ranging), the reflected coherent light can be used to identify chemical constituents. Using further optical detection techniques such as DIAL (DIfferential Absorption LIDAR), real time analysis can be done on smokestack or fugitive emissions released from a facility. These methods employ a "remote spectroscopic system based on light scattering, absorption, or induced fluorescence."[33] A spectroscopic system relies on spectroscopy as a sensing technique. In the vernacular, spectroscopy measures the contents of an effluent by directing a laser through the effluent that potentially contains the target chemical(s) and analyzes the absorbed coherent light of the laser due to the molecular structure of the chemicals. The DIAL technique takes advantage of absorption to identify chemical constituents in a vapor plume. Just as each color of visible light has a unique frequency in the electro-magnetic spectrum, each chemical has a discrete frequency signature and can be identified by spectrum analysis.

Dr. Bernard Stupski of the System Planning Corporation best describes the use of laser frequency differentials to identify constituents:

> An observation is made at a wavelength corresponding to (resonant with) a quantum transition in the atmospheric molecule of interest in either a passive or active mode. A second observation, slightly off-resonance, is then made of the same spatial location to measure the background signal. The difference between the two measurements is

[33] OTA, *Technologies Underlying Weapons of Mass Destruction*, p. 66, quoting Kenneth E. Apt, Los Alamos National Laboratory, "Near-Site Monitoring for Compliance Assessment of the Chemical Weapons Convention," LACP-90-289, June 15, 1990.

> taken as the signal due to the molecule of interest. Two separate wavelengths must be probed for each molecule interrogated.[34]

If the chemical sought is present, the resonant frequency will return a spectral "spike," whereas the off-resonant frequency will give a lower return.

Research done at Battelle produced the following findings on the use of laser based optical sensors:

> Several breadboard and brassboard remote sensing systems using CO_2 lasers and infrared differential absorption LIDAR (IR DIAL) have been developed, under contract efforts sponsored by the DoD and the intelligence community. These DIAL systems have demonstrated (in field test programs) minimum detectable concentration pathlength products (MDCL) of 10 - 20 mg/m² at ranges of 3 -10 km. It is expected that an engineered prototype system can be developed with an alarm threshold set at five times the MDCL, or 50 mg/m², will provide a probability of detection P_D of 95 percent and a false alarm rate P_{FA} of 5 percent. Depending on the cloud geometry and the orientation of the sensor, this prototype system should be able to detect seven of the twelve compounds [listed in Tables 1 and 2 in Chapter IV], even in some cases when environmental controls are in use. However, no attempt was made to determine whether or not the chemical compounds detected represented a unique chemical signature of CW production.[35]

We know what we can detect and at what concentration pathlengths with a 95 percent confidence rate, but we would still need to coordinate further with intelligence efforts to verify a violation of the CWC. This technology is known as IR DIAL not because they use infrared sensing, but because they operate in the infrared spectral region.

Practical application and operating features of laser systems must be considered for aircraft. Current laser sensor systems are fairly large and possibly too cumbersome to include on an airborne platform. Carbon dioxide lasers are the most common, but solid-state lasers are being developed which are more compact and more capable. Currently,

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[34]Bernard A. Stupski, *Evaluation of the U.S. Open Skies Aircraft for Environmental Monitoring* (Arlington, Virginia: Systems Planning Corporation, 1 August 1994) p. C-1.
[35] Leonelli and Smith, "White Paper on Analysis of Stack Emission Signatures from Chemical Agent Production Sites," p. 6.

solid state lasers are inefficient in the 8 - 12μm region, but advances are being made. Mr. Steve Gotoff of the United States Army's Edgewood Research, Development and Engineering Center (ERDEC) in Aberdeen, Maryland indicated that laser based systems are not a very mature technology, and therefore may have implementation problems and high costs.[36] A study by the Defense Nuclear Agency (DNA) on potential follow-on sensors for OST aircraft to perform environmental monitoring had this to say about LIDAR, generally agreeing with Gotoff:

> LIDARs are most useful for measurement of atmospheric constituents (trace species)....Special techniques have been developed for detection of atmospheric species- DIAL (Differential Absorption LIDAR) uses two frequencies for detection and discrimination....Installation costs for a LIDAR are estimated to be high. Commercial airborne systems are not available and would require development. Also, a gimbaling mechanism will be required for pointing the sensor, and some type of tuning mechanism is needed to permit application to the largest number of potential pollution species....Crew workload will increase and special training will be needed for the operation of a LIDAR.[37]

The United States government has spent over $50 million on research for these systems, and plans to invest more to develop an airborne DIAL system that will fly in a C-135 type aircraft (incidentally the base model of the OC-135, the U.S. Open Skies aircraft). There are currently two programs to develop IR DIAL technology. The first, CALIOPE (Chemical Analysis by Laser Interrogation Of Proliferation Effluents), is sponsored by the Department of Energy (DoE), and is being studied by Lawrence Livermore National Laboratory. A spin-off of CALIOPE is the Project N-able, which is a joint effort by the DoE, the U.S. Army, and the U.S. Air Force.[38]

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[36] Interview with Steve Gotoff, Edgewood Research, Development, and Engineering Center (ERDEC), Aberdeen, Md., April 4, 1995.
[37] Defense Nuclear Agency, *Preliminary Sensor Evaluation Briefing, Open Skies Follow On Sensor Evaluation*, October 1994, Chart 18 narration.
[38] Correspondence with Leonelli, October 18, 1995.

Digital signal processing is the last portion of the IR DIAL system. Digital signal processing, with analog to digital conversion, allows integration of computer software with algorithms to process feedback in real-time. Video terminals have been incorporated in some systems to provide quick reference capabilities for operators.

Systems developed for the Army designed for battlefield detection can weigh from 75 to 250 pounds, occupy from three to 12 cubic feet, and require two kilowatts and a 28 volt DC, 110 volt AC power supply.[39] Costs of laser-based systems range from $300,000 to over two million, depending on capabilities and processing.[40]

LIDAR as a technology has existed for over thirty years. Over forty countries are currently involved in research and development of LIDAR systems. LIDAR systems are widespread: the Russian military has the world's only fielded CW laser remote sensing system, the Hungarian military has developed a helicopter-mounted system, the Czech Republic has developed a truck-mounted system, and the Slovak military has developed a man-portable system for battlefield use.[41]

B. INFRARED SENSORS

Thermal imaging is based on the concept that all objects in our environment have a temperature and absorb or emit heat. The infrared band of frequencies is in the frequency band just below the range of visible light and above the radar and radio frequency bands on the electro-magnetic spectrum. Different substances will emit or absorb differing amounts of heat that distinguish them from their surroundings. Depending on the sensitivity and spectral region of an IR sensor, extremely small temperature gradients can be discernible. Infrared sensors have an advantage over radar and optical sensors because they can sense passively, requiring no emitted or reflected

[39] Hughes Corporation, Proprietary Proposal for the RELIENTS System Consortium prepared for the U.S. Army, undated 1994 paper, pp. 12 & 16.
[40] Correspondence with Leonelli, September 29, 1995.
[41] Correspondence with Leonelli, November 30, 1995.

radiation. Infrared sensors monitor ambient background radiation. All matter has temperature, and temperature differentials are used to distinguish differing matter. Colder matter absorbs heat, while warmer matter emits heat, and these absorptions and emissions have frequencies that are read by IR sensors. The same electro-magnetic window of 8 - 12μm exploited by laser technology to detect chemical constituents is also used by IR technology for its detection and identification.

Infrared sensors operating in the spectral region of interest have been tested for U.S. Army battlefield use but not extensively tested for fixed wing platforms. These systems are designed for short range, battlefield detection of CW clouds threatening troops, not against production sites. The current system being tested by ERDEC is known as the LSCAD, or Lightweight Standoff Chemical Agent Detector.[42] The LSCAD has been flown on unmanned airborne vehicles. The LSCAD is the successor to the M21, a vehicle-based FTIR used by the U.S. Marines in during the Gulf War. It is intended for use on a potentially contaminated battlefield, scanning the close environment for CW agents, with an alarm system to alert troops of their presence. This technology should be readily adaptable for use on an airborne platform such as the Open Skies aircraft.

The LSCAD consists of three basic components: a scanner (or gimbal), the IR detector, and the electronics module. Its scanner automatically searches with a 360 degree sweep; this would be modified to be aimed at specific effluent plumes from suspect facilities. The IR detector is a Michaelson interferometer operating over the 8 - 12 micron region at scan rates to 40 spectra per second. A cryogenically cooled HgCdTe (Mercury, Cadium, Telleride) detector is used to acquire an interferogram. The data system uses a 16-bit analog to digital converter coupled to a high speed digital signal processor to interpret the spectra in real time. Interferents are recognized and rejected,

[42] William Lagna, "Lightweight Standoff Chemical Agent Detector," ERDEC, undated point paper. This entire paragraph is taken from information in this paper.

substantially lowering the possibility of a false alarm. The LSCAD weighs 46 pounds and consumes 23 watts at 24 volts.

The LSCAD views a vapor cloud by receiving a line of sight spectral emission or absorption signature in the 8 -12 μm region. The relative temperature differential between the target cloud and the background determine whether the vapor will absorb or emit spectral energy. A large temperature differential will significantly enhance detection sensitivity. Detection sensitivity is expressed as the average concentration of the cloud multiplied by the effective pathlength, or CL, the same as the LIDAR measurement. Aerial use of an IR system similar to the LSCAD could exploit the temperature differential between the ground surrounding a facility and the effluent plume emitted by the facility. A ground based system may not have this benefit, unless mountains are behind the facility from the detecting aspect.

Conversations with Steve Gotoff of ERDEC revealed promise for use of IR sensors as an airborne CW production detector. Specifically, an FTIR, or Fourier Transform IR system held much promise and is being developed by several different institutes. A Fourier Transform Infrared spectrometer employs the Fourier (wavelength/time) transform algorithm to reduce signal acquisition time and improve the signal-to-noise ratio. This algorithm has varied applications, including enhancement of radar processing. Gotoff considered FTIR systems more mature than LIDAR systems (that is, more developed and advanced) and less costly.

Whereas a LIDAR system may cost at least $300, 000, a commercial FTIR system may cost as little as $40,000[43]. Similar to LIDAR systems, FTIR systems need to be aimable, using a gimbal to maintain a scan on an effluent for confident chemical constituent identification. Each system would require a scan time on the effluent plume of approximately 90-120 seconds, much longer than the time required to fly over a facility.[44] On the whole, Gotoff felt IR sensors held more promise for use in this field.[45]

[43] Correspondence with Leonelli, September 29, 1995.
[44] Ibid.

Dr. Leonelli, in the noncompliance model, concluded in the CW noncompliance study that an FTIR should have no problem detecting and identifying sarin, although his modeling was done at a range of one kilometer, well short of the ranges desired or required for an OST aircraft.[46] FTIR technology is being used to monitor fugitive emissions by the chemical industry within facilities. Like LIDAR, it is a widespread technology, being developed in many foreign nations.[47]

C. CONCLUSIONS

After examining LIDAR and FTIR sensing technologies, each is capable of performing the role of airborne detection of CW and component chemicals for producing CW. A third technology considered to have potential for examining chemical effluents is the multispectral scanner, although it has not demonstrated effective ranges beyond one kilometer and is still immature. If either IR DIAL or FTIR were to be used in this context, the primary operational parameters for incorporation would be detection range, required scan time, probability of error, and quantity of chemicals simultaneously searched for. Joseph Leonelli has stated that both of these technologies have similar implementation concerns for airborne use, especially from Open Skies altitudes. "For airborne applications, at 30,000 feet or 10km [OST altitudes], either at slant angle or looking straight down, [Battelle's] analysis indicates that DIAL systems will out perform FTIR for slant angle applications, but performance is comparable looking straight down. This has more to do with atmospheric and background effects than range and instrument configuration."[48] Steve Gotoff felt that FTIR has more potential,[49] but both of these technologies are capable of airborne chemical detection

[45] Interview with Gotoff, April 4, 1995.
[46] Leonelli and Smith, "White Paper on Analysis of Stack Emission Signatures from Chemical Agent Production Sites," p. 6.
[47] Correspondence with Leonelli, November 30, 1995.
[48] Correspondence with Leonelli, October 18, 1995.
[49] Interview with Gotoff, April 4, 1995.

These are the primary technical concerns for the technologies involved. Further analysis of political and proprietary concerns may reprioritize the parameters, examining costs, operational considerations, and detectable chemicals excluded rather than included. The following chapters outline these concerns.

VI. BACKGROUND AND INTENT OF THE TWO TREATIES

This chapter explores the background and intent of the Open Skies Treaty and the Chemical Weapons Convention. It provides the basis for analysis of inter-treaty convergence and divergence offered in the next chapter. Although both treaties are part of a larger body of arms control measures, the overlap between the two is tenuous and their intent is at odds. There are many complementary aspects of OST for the CWC, but there are many obstacles to overcome before it would be possible to integrate these treaties.

A. THE OPEN SKIES TREATY

The Open Skies Treaty (OST) is a confidence-building pact between former Cold War rivals. It is the result of negotiations by two entities at opposite ends of the transparency spectrum – NATO and the Warsaw Pact. The West's proposal called for extensive transparency, while the East's proposal called for exclusivity. Many of the existing compromises were reached after the dissolution of both the Warsaw Pact and the Soviet Union. According to Jonathan Tucker, "[The Warsaw Pact and Soviet Union's] primary problem with the NATO proposal was its intrusiveness, which they considered excessive."[50] Issues of sovereignty, the right to secrecy, commercial rights from excessively intrusive searches and the potential for industrial espionage impede the addition of air sampling equipment to OST aircraft.

The Open Skies Treaty was conceived in 1955 by President Eisenhower as a confidence-building measure between the two Cold-War blocs. It called for an exchange of unarmed reconnaissance flights to observe military and national security activities. It

[50] Jonathan B. Tucker, "Negotiating Open Skies: A Diplomatic History," in Smithson & Krepon, eds., *Open Skies, Arms Control and Cooperative Security* (New York: St. Martin's Press, 1992), p. 19.

was a vehicle for transparency in the pre-satellite era. It was summarily rejected by Premier Khruschev as tantamount to espionage. In 1989 the Bush administration revived the idea of unarmed reconnaissance flights in a quid pro quo fashion "for three reasons: to offset Gorbachev's dramatic disarmament proposals, which had upstaged U.S. initiatives and sparked criticism of the administration's slow pace on arms control; to divert attention from the divisive intra-alliance debate over the modernization of short-range nuclear forces, which threatened to overshadow the May NATO summit in Brussels; and to test Gorbachev's glasnost."[51] Ultimately, these political motivations became moot following the dissolution of the USSR. However, the resulting instability in Eastern Europe and the Former Soviet Union still gave the Treaty a significant purpose – confidence-building. According to Dr. Thomas Karas, Senior Associate of the International Security and Commerce Program in the Congressional Office of Technology Assessment (OTA), "The Open Skies regime of mutual overflights should be seen primarily as a confidence-building measure, not an arms control monitoring or verification measure, nor as one that will add greatly to U.S. intelligence collection."[52]

The Open Skies Treaty was revived as a bloc-to-bloc transparency measure. In the aftermath of the Cold War, however, it has evolved into a country-to-country confidence-building measure. It was signed by all sixteen NATO countries, all former Warsaw Pact countries, and four former Soviet republics – Russia, Belarus, Ukraine and Georgia. The treaty is open to any nation by consensus approval.[53]

In 1989, the OST was meant to build confidence along both sides of the Iron Curtain between ideological rivals. Today, as it is beginning implementation, it acts as a *de facto* pact to calm fears of the former Warsaw Pact nations and former Soviet

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[51] Tucker, "Back to the Future: The Open Skies Talks," *Arms Control Today*, 20 no. 8 (October, 1990) p. 20.

[52] Thomas Karas, Senior Associate, International Security and Commerce Program, Office of Technical Assessment, prepared statement to the Senate Committee on Foreign Relations, *Treaty on Open Skies*, 102d Cong., 2d sess., September 22, 1992, p. 28.

[53] Statement released by the White House Press Secretary, 3 Nov 1993, *U.S Department of State Dispatch*, 15 Nov 1993, v4 n46 p792.

Republics that the Russian Republic is complying with its disarmament agreements. These participants are clamoring to fly over Russia, while only the Russia-Belarus bloc has requested to overfly the United States. The Benelux countries, Belgium, Luxembourg and the Netherlands, are participating as a bloc as observers, but individually as observed states. This means they will conduct overflights in unison, but host overflights individually. Russia and neighboring Belarus will act as a bloc in both capacities, as will the former Czechoslovakia, now Czechia and the Slovak Republic.

Each participant nation has both a passive quota and an active quota for flights. The active quota, or number of overflights a party is allowed to conduct, is the annual number of overflights a state may perform within the Open Skies regime. The passive quota is the number of annual overflights a state is subject to by treaty. This number was determined by the geographic size and importance of the state. Russia-Belarus and the United States will accept forty-two overflights of their territory each year. The next tier, at twelve flights each, includes Canada, France, Germany, Italy, Turkey, Ukraine and the United Kingdom. The smallest passive quota is Portugal's, at just two. During the first three years, as the treaty is being implemented, passive quotas will be capped at seventy-five percent of the treaty's quota. During these three years, the United States and Russia-Belarus will accept a maximum of thirty-one overflights. A signator's passive quota will not exceed its passive quota.

The most sensitive Open Skies negotiations involved intrusiveness. Negotiators considered the sensors proposed. They were interested indetermining what level of intrusiveness, sensitivity and accuracy in intelligence collection will be conceded during an overflight. The potential intelligence compromised during an overflight of the United States outweigh the benefits of intelligence collected during a United States overflight. Because of America's sophisticated network of satellites and reconnaissance aircraft, the quality of data collected by U.S. Open Skies overflights will be far inferior to that collected by an OST overflight. The difference with Open Skies flights will be the

flexibility of timing and the ability to collect data that a satellite may not be able to due to overcast weather. The United States' unilateral and multilateral advantage from the OST is in political goodwill, transparency, and intra-regime confidence-building. Political goodwill comes from the transparency and confidence building afforded by the OST.

The technology gap between West and East emerged during the negotiations of the Open Skies treaty. The Soviet bloc insisted on cruder and duller resolution technologies, while NATO nations pressed for inclusion of more advanced technology, although not state-of-the-art (probably because all sensors used for flights must be made commercially available to all participants). There was discussion of whether to allow all-weather and nighttime sensing capabilities. With some modifications and reduced capabilities, all-weather and nighttime capabilities were allowed. The sensors finally agreed upon were:

1. Optical panoramic and framing cameras; resolution of 30 centimeters.
2. Video cameras with real-time display; resolution of 30 centimeters.
3. Infra-red line scanning devices; resolution of 50 centimeters.
4. Sideways-looking synthetic aperture radars (SARs); resolution of 3 meters.[54]

A resolution of thirty centimeters (roughly one foot) for all cameras was agreed upon because it will enable an observer to distinguish between, for example, a truck and a tank, but not the *type* of truck or tank. The infrared devices allow for effective sensing when vision may be obscured. Through their heat sensing, IR sensors can determine the operational status of facilities such as airports, military bases and industrial sites, such as chemical facilities.[55] These would complement optical devices during unclouded weather, but if used as a primary sensor, they will not have the resolution to distinguish between certain objects. The relative insensitivity of the SARs, with a resolution of approximately

[54] The Open Skies Treaty.
[55] WEU Document 1364, "Technical co-operation in the framework of the Open Skies Treaty," 17 May 1993.

ten feet, is intended to allow only for the detection of concentrations of trucks, tanks, artillery or other armaments. SARs need to be supplemented with other sensors to amplify their findings. Similar to the infrared sensors, SARs are capable of detection at nighttime and during obstructed weather.

Article II, paragraph 4 of the treaty defines observation aircraft as "unarmed, fixed wing aircraft designated to make observation flights, registered by the relevant authorities of a state party and equipped with agreed sensors."[56] The United States will use two converted WC-135 weather reconnaissance aircraft, redesignated OC-135 for their overflights. Variants of these airframes are used by the U.S. Air Force for cargo transport (C-135), tanking (KC-135), and real-time reconnaissance and intelligence (RC-135). The OC-135 aircraft will be outfitted with the appropriate sensors and will be flown under the authority of the On Site Inspection Agency (OSIA), the cognizant authority for U.S. OST implementation. Typical missions should last approximately ten hours and cover distances of 4,000 miles.[57] Other participants will use appropriate fixed wing aircraft to conduct their overflights, but all will have sensor suites with similar capabilities. Interestingly, Russia and Germany will each use a Tu-154 aircraft, used by the defunct German Democratic Republic to transport Erich Honneker.

The use of illegal sensors was a concern of many signatories. Two measures in the OST try to eliminate this concern. First, an eight-hour period is alloted for aircraft inspection by the host state's representatives before each flight. The Russians insisted on this right to ensure that no hidden, or unauthorized sensors are used. Second, an agreement was reached that an observed state could insist on the use of their Open Skies aircraft by an observing nation, known as the "taxi" option. This measure would prevent unauthorized sensors to be used during an inspection flight

[56]Open Skies Treaty, 24 March 1992.

[57]Ley W. Kandebo, "USAF to Modify Second Open Skies' WC-135 in 1994," *Aviation Week & Space Technology* 139 p59-61 (October 25, 1993).

The most historic compromise achieved by the negotiators of the Open Skies Treaty was that of territorial access. Negotiators from NATO countries insisted on broad access with very few limitations or restrictions, while negotiators from the East wanted to maintain restricted areas and exclusion zones for overflight. The Soviets were seeking to include overflight of U.S. overseas military installations, but this was later dropped by the Russians. The United States actually had some reservations about flights over sensitive operations areas, but realized that gaining full access to other's territories meant granting full access to theirs. The final agreement led to full access of all territories. John Hawes, United States negotiator to the OST, stated, "All parties are obligated to permit observation of their entire territory. The observation flights will be conducted on the basis of a mission plan submitted by the observing party, which may only be modified in the event of specific threats to flight safety."[58]

This is the first treaty to ever grant complete access to all territories of all participants, essentially "challenge" inspections for each overflight. An important feature of this comprehensive, intrusive access is that it will supplement the Conventional Forces in Europe agreement (CFE). Whereas the CFE application was limited to areas west of the Ural Mountains in Russia, the OST will allow areas east of the Urals to be monitored when desired within the framework of the treaty.

The Open Skies Treaty will be implemented incrementally, both in quantity of flights and quality of data collected. Initial OST overflights will place restrictions on certain sensors. Only seventy-five percent of the flight quotas will be conducted in the first three years, after which the full number of flights called for by the quotas will be flown. Additionally, during this initial phase only the photographic equipment and SAR will be used for monitoring. The infrared sensors will be introduced after this period. There is potential for other sensors to be added as desired by participants through

[58]John J. Hawes, prepared statement to the Congressional Committee on Foreign Relations, United States Senate, One Hundred Second Congress, Second Session, September 22, 1992, U.S. Government Printing Office, Washington, 1992, p. 4.

consensus approval. This may eventually include air sampling sensors. The treaty must enter into force first, and prove the value of its existing sensor suite before additional sensors would be tabled for negotiation. The first flight will launch sixty days after the twentieth ratification of the treaty. These twenty must include Canada and Hungary, who are the Depositories for the Open Skies regime, and any signatory with a passive quota of eight or more flights. As of the autumn of 1995, ratification by Russia, Belarus, and Ukraine were still needed for the treaty to enter into force.

Data collected on overflights will be shared by the observing and observed parties, in the form of raw film or magnetic tape. The treaty does not allow film which may be computer enhanced, since this would defeat the purpose of the agreed-upon crude resolution. Since participants are limited to their annual active overflight quotas for other nations, copies of this raw data can be purchased by any participant in the Open Skies regime. Under the treaty, this data will not be made available to non-participants. The major difference in examining raw data collected by another party versus your own data is the choice of flight path and concentration on certain areas of interest. For example, if France is about to overfly Russia-Belarus and chooses to concentrate its flight path on Siberia, this may distress Ukraine if it is seeking timely information on a Russian military exercise conducted in central Russia.

Amendments can be proposed by any party to the treaty. Any three parties proposing the same amendment may convene a conference of all signatories to discuss this proposed amendment. All treaty signatories must agree to the amendment, after which it must be ratified in the same manner as the treaty. Air sampling devices have already been discussed as a new sensor for the sensor suite, primarily as an environmental sensor.

B. THE CHEMICAL WEAPONS CONVENTION

The Chemical Weapons Convention (CWC) is the most comprehensive and intrusive multilateral treaty ever signed. The CWC prohibits the development, production, acquisition, stockpiling, retention, transfer, and use of CW.[59] The CWC even prevents assistance to other states or actors in acquiring a CW capability. It is a verification pact which involves the monitoring of both government and commercial sectors of chemical production, requiring extensive reporting procedures to be followed by each. It is the first treaty ever to eliminate an entire category of weapons. Only three states have admitted CW programs: the United States, Russia, and Iraq. An unclassified intelligence assessment states that currently twenty states have CW and another ten are attempting to acquire them.[60] The CWC calls for the destruction of any CW stockpiles and production facilities.

The CWC was extremely difficult to negotiate due to the dual use of many precursor chemicals and chemical processes. The treaty had to strike a balance between intrusion for verification and respect for states' and commercial rights to privacy. It had to be intrusive enough to determine compliance without violating proprietary rights, causing excessive shutdown costs for facilities, or intruding on states' sovereignty.

The CWC has been signed by 159 states as of October 1995, and encourages accession by all the world's states. There are only 31 states that have not signed, the majority of which are either of two categories: small, poor states, or Arab states refusing to sign in protest against Israel's refusal to sign the NPT. The CWC does not need universal adherence to be effective, but unanimity would enhance its effectiveness.

Negotiators of the CWC devised three schedules of controlled chemicals according to toxicity, and military and commercial utility. The chemicals with high

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[59] Smithson, *The Chemical Weapons Convention Handbook* (Washington, D.C.: The Henry L. Stimson Center, 1993) p. iii.

[60] Correspondence with Leonelli, October 18, 1995.

toxicity levels and almost singular purpose as CW, with little or no commercial utility, were placed on Schedule 1. These include many nerve agents, such as sarin, soman, and tabun, and their precursors. States may produce these chemicals under the CWC in a quantity of up to one aggregate metric ton annually, for the purpose of research, medical, pharmaceutical, and protective studies. Other restrictions placed on Schedule 1 chemicals include number of facilities handling and producing them, reasons for production, such as vaccinations, antidote testing and mask testing, and quantities transfered to other states for these same purposes.

Schedule 2 chemicals have low to moderate commercial application, but are considered high risk because they can be used as CW or precursors to CW. Commercial products made from Schedule 2 chemicals include herbicides, pesticides, ceramics, and ballpoint pen ink.

Schedule 3 chemicals are used in large quantities by commercial industry, but still pose a risk because they have been used as CW or as precursors for CW. Commercial products made from Schedule 3 chemicals include agricultural chemicals, flame retardants, plastics, pharmaceuticals, dyes, and detergents.

Once the CWC is ratified and begins entry into force, the Organization for the Prohibition of Chemical Weapons (OPCW, the CWC's administrative organization) will establish a baseline database of CW possesors, producers, and potential for CWC prohibited activities. States will declare CW production, storage, and destruction sites, and commercial declarations will also be made for sites with capabilities to produce CW. Within 30 days of the CWC's entry into force, states must declare the nature of activities at commercial industrial sites that produce chemicals on Schedules 2 and 3 of the CWC. This baseline database for CWC verification procedures will be updated annually. Quantitative thresholds have been set for chemicals on these two Schedules. If a facility exceeds annual limits for allowed production, intermediate reports must be submitted. Additionally, any facility which has produced, processed, or consumed above threshold

quantities of Schedule 2 chemicals in the three years prior to entry into force, or expects to exceed that quantity in the coming year, must report so. Schedule 1 chemicals are tightly controlled, whereas Schedules 2 and 3 chemicals are closely monitored. As does the convention, the Schedules try to balance intrusion and verification against the risk of noncompliance.

The CWC verification procedures include two types of inspections: routine and challenge. Routine inspections will encompass declared production, storage, processing, and destruction facilities. Challenge inspections may encompass undeclared sites under certain conditions. Scope, timing, and depth of routine inspections will depend on the Schedule of the chemicals involved. Schedule 1 facilities allow for the most intrusive inspections. These inspections will be conducted on short notice with unimpeded access, allowing inspectors to mark and seal items for future reference. Schedule 1 sites may be continuously monitored by on-site monitoring devices such as those used in Iraq – camera surveillance and electronic anti-tampering devices.

Routine inspections of facilities pertaining to Schedules 2 and 3 chemicals are less intrusive and timely than those for Schedule 1. Notification of inspection times for facilities vary from 48 hours for Schedule 2 to 120 hours for Schedule 3. Access is in principle unimpeded, but extent of access is based on the initial baseline inspection of a declared site. Inspectors will be allowed to request pertinent information, interview personnel at the site, inspect documentation and records, have host personnel take photographs and samples, and use monitoring instruments.[61] Inspections on Schedule 2 and 3 sites become routine if the facilities produce more than threshold amounts of pertinent chemicals. Production facilities which estimate low on their output, plan to produce slightly less than threshold amounts, or cheat on their reporting procedures, are exempt from routine inspections.

[61] Smithson, *The Chemical Weapons Convention Handbook*, p. 8.

Challenge inspections go beyond routine inspections in that they strive to detect noncompliance through unexpected verification measures. As Smithson writes, "Challenge inspections are designed to detect and deter activities prohibited by the Convention, namely the development, production, storage, acquitsition, transfer and use of chemical weapons."[62] A challenge inspection is requested through the Technical Secretariat, who is obligated to notify the subject state at least 12 hours before inspectors arrive at the point of entry. Inspection teams are composed of inspectors from states other than the challenging and challenged states. The Executive Council of the CWC can stop a challenge inspection if three-quarters of its 41 members deem the request for inspection to be abusive or frivilous. There is a strict timetable for the inspection, putting the inspection team at the perimeter of the site to be inspected no later than 48 hours after the notification given by the Technical Secretariat.

Over the next seventy-two hours, the inspectors and the host officials will negotiate both the final dimensions of the perimeter, which must be at least ten meters outside any building or security structure, and the nature of the access that the inspectors will receive inside it.[63] Inspectors may take air, soil, and effluent samples and may use monitoring equipment within a 50 meter band of the perimeter. This negotiation is done under the principle of managed access. Challenge inspections are conducted under the principle of managed access, meaning that the inspectors and hosts will negotiate the extent of access to any particular place within a site, the nature of the inspector's activities, and what information the host officials will provide to the inspectors. The perimeter of the site is secured and negotiations begin. Inspectors review traffic logs, take photographs and videos, and receive escort within the perimeter. The CWC allows air, soil, and effluent samples to be taken. Monitoring devices, such as a mass spectrometer or a gas chromatograph, may be used within a 50 meter band around the perimeter. Managed access again balances the inspector's verification procedures with

[62] Ibid., p. 8.
[63] Ibid., p. 9.

the host state's right to protect sensitive national security and commercial proprietary information.

Challenge inspections are limited through negotiated managed access and in number per year. Managed access ensures that each challenge inspection will be different due to the negotiated settlement between inspectors and host officials. Concerns about industrial espionage and national security secrecy are rightly founded, but cooperation and proper access should alleviate these fears. If the Executive Council finds that the state party requesting a challenge inspection has abused the intent under the CWC, it can recommend that that state bear some or all of the financial burden of the inspection. Challenge inspections are limited to twenty per year for a given state and two per year at any given facility.

The CWC attempts to eliminate an entire category of weapons of mass destruction. Proprietary information is safeguarded and classified by the OPCW to protect commercial rights. Signatories to the CWC that are attacked with CW have security assurances from other signatories, and noncompliers lose their priviledges under the CWC, as well as facing international condemnation. Its procedures are bounded to protect states' and commercial rights, but it is also a cooperative verification pact, allowing enough intrusion to ensure compliance in most scenarios.

This chapter has laid out the background and basic principles of the Open Skies Treaty and the Chemical Weapons Convention. The OST is a cooperative, confidence building pact, giving states unrestricted territorial access to overfly each other with resolution-limited sensors. The data collected by any given state is available for purchase by any signator. Sensor symmetry is achieved for the Open Skies through baseline standards equal commercial access to technologies. The CWC is an extremely intrusive pact attempting to eliminate an entire class of weapons. It requires indepth reporting procedures by both states and industry. The CWC challenge inspection is limited

through access negotiated by inspectors and an inspected state, with each inspection being unique.

VII. POINTS OF CONVERGENCE AND DIVERGENCE BETWEEN THE TREATIES

Would the incorporation of air samplers into the Open Skies sensor suite be able to complement Chemical Weapons Convention verification? Technologically, air sampling from OST altitudes is possible. There are many ways OST aircraft, especially with air samplers, could make the CWC verification process more efficient and effective.

Although these treaties are both in the arms control realm, the OST is a confidence-building regime whereas the CWC is a verification regime. This dichotomy may prove too great a gap to close between the pacts to allow a complementary role. This proposal must become a priority for treaty signatories before it will be politically feasible.

A. ARGUMENTS FOR

The Open Skies Treaty, through its broad but shallow surveillance measures, can assist the verification of other treaties. The OST is broad in its territorial access, yet shallow through the insensitivity of its sensors. The preamble of the OST notes, "the possibility of employing such a regime to improve openness and transparency, [and] to facilitate the monitoring of compliance with existing or future arms control agreements..."[64] The OST is a de facto complement to the Conventional Forces in Europe Treaty (CFE). The CFE is geographically limited in its verification to areas west of the Ural Mountains in Russia. The OST, with its unrestricted territorial access, allows observation of all of Russia. The intelligence gained through OST overflights allows myopic verification of Russian security activities akin to CFE measures.

[64] The Open Skies Treaty, Preamble, p. 1.

Similarly, OST overflights could complement verification of the CWC. All members of the OST are signatories to the CWC. Open Skies aircraft could overfly facilities of interest to the CWC inspectorate, using available sensors. CWC activities include monitoring declared CW stocks, facilities, and the single small-scale production facility allowed by the CWC. Other tasks include monitoring transfers of permitted quantities of agent and movement of CW stocks to demilitarization sites; destruction of CW stocks, associated equipment, and facilities; and commercial chemical production.[65] As Smithson and Krepon write, "The large number of sites to be covered, the difficulty in pinpointing CW monitoring signatures, and the legitimacy of commercial operations that could subsequently be reoriented to military applications make the verification tasks facing the CWC inspectorate dwarf those of other treaties."[66] Many of these tasks could be accomplished by the use of aerial inspections. Overflights could make major cleanup operations, movement of equipment and stocks, or other ambiguous activity more difficult and noticeable at suspect sites.[67] This would help those states without the benefit of NTM more than those with. Krepon says, "aerial surveillance is an enabling instrument, allowing states of modest means to play a constructive role in the treaty implementation and verification process."[68] The Organization for the Prohibition of Chemical Weapons (OPCW) is an international organization, and would use any assets allocated to the benefit of all regime members.

With its existing sensor suite, OST aircraft could economize CWC verification. Overflights could provide facility layout photographs to assist planning inspections. With existing Open Skies IR sensors, overflights could sense facility operating temperatures to assist identifying production processes used or target active pipelines

[65] Smithson and Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections*, Occasional Paper No. 4 (Washington, D.C.: The Henry L. Stimson Center, April 1991) p 2.
[66] Amy Smithson and Michael Krepon, "Strengthening the Chemical Weapons Convention Through Aerial Inspections" (Henry L. Stimpson Center, Washington, D.C., 1991), p. 2.
[67] Smithson & Krepon, eds., *Open Skies, Arms Control and Cooperative Security*, p. 229.
[68] Krepon, "Open Skies and Multilateral Verification," in John G. Tower, James Brown, and William K. Cheek, eds., *Verification: The Key to Arms Control in the 1990s* (Washington, D.C.: Brassey's, 1992), p. 109.

within a facility. With the addition of air sampling sensors, the OST could further assist verification of the CWC through targeting of facilities and searches for specific chemical constituents, similar to an urinalysis screening for illegal drug use. Smithson and Krepon state,

> Overflights would allow inspectors to orient themselves and plan ground inspections more effectively and efficiently. Overflights that incorporate the use of sensors would permit the development of a data archive, an institutional memory essential for an international inspectorate with rotating personnel. Futhermore, use of aircraft would make overhead data available to the Secretariat and the CWC member states that may not have assured access to national technical means...of verification....The Secretariat...could use information gathered through aerial inspections to target OSIs more effectively, an important consideration given the limited quota of OSIs that are...allowed.[69]

Coordination between OST overflights and the CWC inspection regime could enhance the CWC's verification.

The OST acts as an intelligence source. For the United States, there are many other intelligence sources with higher resolution than the OST sensor suite, but for some signatories without NTM, the OST will be an invaluable source of intelligence. The use of air samplers on OST aircraft to search for illicit CW production could trigger CWC challenge inspections. American intelligence sources will coordinate closely with the United States' OST overflights to plan their routes and targets of interest along those routes.[70] The feedback from these flights will be used to complement existing intelligence. Within the web of arms control treaties, there is a cumulative effect from each new source of data. Adding air sampling sensors to the OST sensor suite will add to the capabilities of not only the OST regime but to the CWC as well. Smithson and Krepon, for example, conclude, "The addition of aerial inspections can have useful

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[69] Smithson and Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections*, pp. 2&5.

[70] Interview with RADM Bill Center, USN, November 9, 1995. This was confirmed by Lt Col Jim Chamberlain, USAF, Arms Control and Disarmament Agency, phone conversation on October 5, 1995.

synergistic effects, strengthening the Secretariat's ability to analyze data, conduct ground inspections of various kinds, and deal with questions concerning compliance."[71]

Timing is a key factor for the detection of noncompliance from an airborne platform. A facility must be emitting an effluent plume containing the chemical constituents sought for detection of illicit CW production by air samplers. If a state were to shut down operations at a facility because the facility in question was in the flightpath of an OST overflight, this may raise suspicion of illegal activity. As Smithson and Krepon note, "The disapproval of proposed flight plans or sensors could also suggest the need for further investigation."[72] The OST allows roughly 100 hours from notification until takeoff of an overflight – enough time for the OST flightplan to be reviewed by an inspected state, and any illegal activities along the flightpath to be shutdown. Termination of certain batch processes, however, may cause the loss of in-process chemicals.

The producer of CW would need to weigh the risk of detection against the urgency for the CW. If not shut down, this production may risk airborne detection and trigger a CWC challenge inspection. In all probability, notification and timing are the key hindrances to an effective air sampling trigger of CWC noncompliance because the overflown state would make sure the "smoking gun" is no longer smoking when the overflight occurs. To detect CW from an aircraft, the timing would need to be very fortuitous, and the producer must take the risk of detection. Even so, air samplers on OST aircraft can be effective even if they never detect a "smoking gun." Air samplers will make CW production more difficult and risky for those states not choosing to comply. As the Canadian government commented, "When adequate verification

[71] Smithson and Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections*, p. 18.
[72] Ibid., p. 4.

increases the risk of detection that a violator would face, the temptation to seek advantage violating an agreement is reduced and deterrence is enhanced."[73]

Air samplers will make the OST more intrusive, but they could make the CWC less intrusive by reducing the requirement for on-site inspections. The addition of a sensor that can detect the effluents of industrial facilities may not be desired by some states. If the use of this sensor can result in fewer OSIs, however, then many states may support additional sensors. "Aircraft may increase detection probabilities [of CW production] without undue increases in intrusiveness or expense....Increased use of remote capabilities could enable inspectors to finish their jobs more quickly and, possibly, to forgo more extensive inspections on the ground if the overflight can be conducted with appropriate sensors. Use of aircraft would complement rather than substitute for ground inspections."[74] The increase in intrusiveness of the OST could alleviate the intrusiveness of the CWC OSIs.

Another benefit of remote airborne sampling would be that it could perform many verification functions from afar, without placing inspection teams in country. An inspector for the United Nations Special Commission on Iraq (UNSCOM) said that these types of sensors may help to keep inspectors from harm if the inspected nation becomes belligerent.[75] These sensors cannot replace on-site inspectors, but may assist at critical points in the inspection process of a country. Future enhancements to the technologies involved, increasing their range and sensitivity, may increase their role further, placing them on higher flying platforms and even satellites.

Air sampling sensors are only one of many means for detection of chemical weapons production, and certainly not the most prominent or desirable. Yet through aerial detection, a much larger geographic area may be observed in a much shorter time

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[73] *Verification in All Its Aspects: A Comprehensive Study on Arms Control and Disarmament Verification Pursuant to UNGA Resolution 40/152(o)*, Government of Canada (Ottawa: April 1986), p. 16

[74] Smithson and Krepon, *Strengthening the Chemical Weapons Convention Through Aerial Inspections*, p. 5.

[75] Interviews with UNSCOM inspector, not-for-attribution, April 1995.

and may be able to narrow or focus on-site inspections. Aerial detection may also give initial indications of previously unknown sites for these processes regarding chemical weapons. This in turn may warrant the challenge inspection provisions of the CWC to be implemented, or at least focus intelligence assets to concentrate on this new area of suspicion. In turn, this can save the OPCW time and money in its inspection process.

B. COUNTER ARGUMENTS

Problems might arise if OST overflights are used to enhance verification of the CWC. The OST is a confidence-building measure, with unlimited territorial access but specific limits placed on the resolution of its sensors. It is a broad but shallow arms control measure. The OST verifies nothing specifically, but monitors many things through dampened (myopic?) intelligence collection. The CWC, on the other hand, attempts to eliminate a specific category of weapons through intrusive and specific verification measures. By using the OST overflights to verify the CWC, the basic confidence-building intent of the OST is shifted. Instead of broad brush surveys, OST overflights move beyond a role of transparency and into verification. In Russia and Eastern Europe, where the intrusiveness of OST was repeatedly challenged during the negotiating process, there may be opposition to expanding OST mandates. Even with rigidly negotiated limits for chemical sampling through sensor tuning limitations, the operation of the OST would crossover into the verification realm.

The OST is a confidence-building treaty, allowing mutual overflights to monitor the general activities of other signatories and build trust. The CWC is an intrusive verification treaty, prohibiting the production, storage, and use of a specific category of weapons, with strict guidelines for its verification. The intent of the OST is not to verify, but to build trust through transparency. Its flights have designated flightpaths and search for no specific activities, but monitor the overall security status of the subject state.

Adding verification procedures to its duties would change the purpose of the OST and run counter its intent.

The memberships of the Open Skies Treaty and the Chemical Weapons Convention also are different. The OST has 27 members, in North America, Europe and Asia. The CWC has over 150 members from all over the globe. All members of the OST are members of the CWC. Attempting to interweave these two treaty regimes through complementary overflights would cause uneven application of a potentially crucial verification measure. An additional problem may arise from how the inspections are conducted. Open Skies overflights are conducted by a flight crew from the inspecting state, with some members of the host state aboard to monitor to conduct of the flight. CWC inspections, on the other hand, are carried out by a nonpartisan international inspectorate. None of the inspectors are allowed to be from the requesting or hosting states, although monitors from these states may accompany a CWC inspection. This could cause administrative problems at least, and at worst, continuity and compliance problems.

Open Skies negotiations were long and arduous, with compromises reached on each point. An especially difficult point of compromise was the sensor suite and corresponding resolution for the sensors. The Soviets/Russians pressed for a minimal sensor suite with limited resolution. The Americans pushed for a broad spectrum of sensors and intrusive capabilities. Air sampling sensors were discussed during the negotiations, but were excluded. They were considered for environmental sensing, but the potential for testing for chemical and biological weapons was also discussed. The Open Skies Treaty can expand its sensor suite to include air samplers, but only by consensus vote. Environmental sensing may be acceptable as a negotiating point, but the use of enhanced sensors for chemical weapons production verification would be unacceptable to most signatories. This shift may require not only an amendment to the

Open Skies Treaty, but possibly renegotiation of the entire accord. There is no formal mechanism in either pact for cross-treaty coordination or complementary roles.

A problem encountered from the American perspective is how to fit new equipment onto the OC-135 aircraft. All available space is already taken by approved sensors or operators and their equipment. Neither LIDAR nor FTIR sensors are very large, but room would have to be made to include these sensors and an operating station within the aircraft. A follow-on issue is time and money spent to train operators of these new sensors. These issues would not be difficult or terribly expensive to remedy, but must be considered when examining this proposal.

The targeting of suspect sites within the Open Skies regime has implications for the coordination of flight planning with intelligence sources. Open Skies flights are flown by an observing state over a host state. Flight monitors from the observed state are included in the crew. Therefore, intelligence sources would need to be protected during the preflight planning or flight itself. HUMINT and NTM intelligence would need to be sanitized to enable it to be carried on an Open Skies overflight. To insure intelligence sources are not revealed, many false "suspect" sites may need to be targeted. That way, actual overflight of suspect sites will not arouse undue suspicion. Further, if a suspect site is extremely isolated from all other points of interest along the intended observation flightpath, the observed party may object and attempt to categorize surrounding airspace as hazardous. Denial of overflight of areas previously designated as safe may confirm the suspicions of the observing party.[76]

C. CONCLUSION

Both the OST and the CWC are intrusive, multilateral, confidence-building pacts. The OST is limited in its intrusiveness by its sensor suite, in quality, resolution, timing,

[76] The OST allows designation of "hazardous" flight areas, which must be excluded from flight paths and can be submitted by signatories, with proper justification, at any time.

and comprehensiveness. The CWC is limited in its verification through its number of inspections and ability to properly focus those inspections on suspect sites, forcing inspectors to maximize their effectiveness. The addition of the aforementioned airborne detection technologies would enhance the scope of each pact. Open Skies would become more intrusive, thus creating greater transparency and further confidence-building, and the CWC would be able to focus its limited inspection resources using the assistance of data from Open Skies overflights. Overall, the inclusion of sensors able to detect chemical weapons production or testing on Open Skies could both complement and supplement the CWC.

VIII. INTERNATIONAL POLITICAL ISSUES FOR INTER-TREATY COORDINATION AND AIR SAMPLERS

The Open Skies Treaty and the Chemical Weapons Convention are made possible by the end of the Cold War. These and other arms control treaties are meant to disarm those who stockpile WMD, and to maintain world stability. Despite the desire to enter these treaties into force, there are certain inherent rights of states and industries that may be infringed by these treaties or by the use of air samplers on OST aircraft. The proposal to including air sampling sensors on OST aircraft may encroach on these rights. These difficulties go beyond inter-treaty issues and into the realm of politics. They include concerns about proprietary information and industrial espionage, sovereignty and secrecy, and whether or not the political will exists to carry out the proposal for OST and CWC cooperation, especially with air samplers aboard. These concerns run counter to the concepts of deterrence, transparency and confidence-building, the basic tenets of both the OST and CWC regimes. They are, however, real obstacles to this proposal and must be addressed.

The first and most plausible argument against this proposal is that it is extremely intrusive. The Soviets had many reservations as the OST was being negotiated, the greatest of which was the intrusive nature of the treaty and the capabilities of the sensors to be used. Peter Jones, a member of the Canadian Open Skies negotiation team, reveals that the Soviets were opposed to the treaty and the potential information it would give to the West. After the dissolution of the USSR though, the now-Russian delegation was more open to prospects for mutual transparency. He also says Open Skies was conceived as an open-ended document, with the intention of expanding its capabilities and sensors, and thus its intrusiveness and therefore transparency.[77] Ronald Lehman says of CWC

[77] Phone conversation with Dr. Peter Jones, Ottawa, Canada, 12 September 1994.

inspections, "Simply detecting covert CW stocks is immensely difficult even before any activity is challenged. The challenge inspection regime itself must then provide a means for reciprocal access to chemical industrial facilities or storage sites without revealing sensitive information relevant to national security and commercial secrets."[78] Nations with nothing to hide have better prospects for mutual confidence-building. Increasing the capabilities of the Open Skies sensor suite can be done incrementally to ensure all parties are comfortable with each increase in transparency. The intrusiveness of air samplers can be controlled through negotiated limits for frequencies and processing equipment.

The inviolability of a nation's sovereignty and its right to secrecy are related issues but separate from the issue of intrusiveness. Allowing a reconnaissance flight anywhere over one's nation sacrifices the right to control actions within a states borders, even with one's own monitors aboard. Similarly, the deep inspections proscribed by the CWC require a great degree of openness. Smithson indicated that many states within the Open Skies regime may not want their air sampled due to possible revelations of unacceptable pollution levels.[79] The right to secrecy opposes the idea of transparency promoted by both the OST and the CWC, but is an inherent right of sovereign states. Acceding to either of these pacts requires the sacrifice of some national sovereignty, but the overall benefits of these regimes should outweigh this sacrifice.

Within the United States, the legality of extreme intrusiveness has been questioned, especially as it relates to the Fourth Amendment of the U.S. Constitution, addressing illegal search and seizure of private property. Even though the Open Skies proposals deal with remote sensing as opposed to on site sensing, their intrusiveness may constitute illegal search under U.S. law. The same may be true in other Open Skies signatories. The CWC was negotiated with the stringent measures of the U.S. Constitution in mind, yet still may find legal challenge as it enters into force. It is

[78] Ronald F. Lehman, "Verification in the Age of *Glasnost* and Open Skies," in Tower, Brown, and Cheek, eds., *Verification: The Key to Arms Control in the 1990s,* p. 7.
[79] Phone conversation with Smithson, 12 September 1994.

estimated that there are over 20,000 chemical companies in the United States alone. Their concerns about maintaining a competitive edge and minimizing regulatory oversight are most likely shared by the international chemical industry.[80] Although there has been cooperation from those fully aware of the CWC in the chemical industry, this may not be a representative sampling of industry behavior. This is an issue that has yet to be determined in a court of law but will surely have its day.

This intrusiveness also concerns many industrial entities trying to protect proprietary information. Their major concern is that data collected may exceed inspection requirements and be tantamount to industrial espionage. This is especially true for enterprising companies experimenting with new technologies in direct competition with foreign companies. Their concerns deal not only with sensor capabilities, but also with access to data collection and its analysis. These concerns are addressed by the fact that the output of both laser-based and infrared sensors can sample exclusively for consituents of chemical weapons production designated in negotiations. Laser-based sensors require tuning to specific frequencies to sample for correlated chemicals.[81] The processing for infrared sensors can search exclusively for those chemical constituents desired by a negotiated list. Chemicals tuned for or processed for would be similar to those in the Battelle study of Chapter IV for a given chemical agent.

The final issue with international implications is political will. Do the states involved in the OST and CWC have the political will to implement such a measure? There are many competing concerns for all states. The OST was re-initiated by President Bush in 1989 to balance all the arms control initiatives brought to the table by Mikhail Gorbachev and to yield political capital. For President Bush, signing of the OST was facilitated by the end of the Cold War. Similarly, the CWC has had a breakthrough

[80] Smithson, ed., "Implementing the Chemical Weapons Convention: Counsel from Industry," Report No. 10, (Washington, D.C.: The Henry L. Stimson Center, January 1994), pp. i&ii.

[81] Detection of other chemicals is still possible. The off-resonance frequency could become the *primary* frequency and vice versa, spiking on the off resonance frequency to test for chemicals which are not agreed upon. This could specifically test for chemicals that are "on" the off-resonance frequency, using the "primary" frequency, tuned to test for the CW constituent, as the off-resonance frequency by design.

period after the Cold War. Many more nations have acceded to the CWC since 1989, but there are still 31 non-signatories worldwide. Has the momentum necessary to ratify and enter these two treaties into force waned? Russia and many Eastern European states have other financial and political difficulties that have priority over enacting the OST or CWC. The CWC can be an effective regime, but not nearly as effective as if its signatories included such states as Iraq, Syria, Egypt, Libya, and Taiwan. Without the impetus to enter these treaties into force, the prospect for placing air sampling sensors on OST aircraft is moot. The U.S. position on this proposal is classified, but interagency negotiations have taken place to discuss it.[82] When the OST and CWC do enter into force, this is an issue which the United States must take a hard look at for cost savings and enhancement of the United States counter proliferation policy.

[82] Phone conversation with Lt Col Jim Chamberlain, USAF, Arms Control and Disarmament Agency Open Skies division, October 6, 1995.

IX. CONCLUSION

There are significant contributions to arms control that can be realized from the incorporation of air sampling sensors into the Open Skies sensor suite. Technologically, air samplers can sense CW production in effluents from OST altitudes (approximately 30,000 feet). These sensors have multiple detection capabilities which can test for environmental degradation, chemical weapons, and potentially biological and toxin weapons. Their potential to narrow the focus of CWC inspections and thus assist in the efficient use of OPCW resources is invaluable. The use of air samplers, while making the Open Skies regime more intrusive, may allow the on-site inspection provisions of the CWC to become less intrusive and, in tandem, more acceptable to some states. The incorporation of air sampling sensors can also help those signatories without their own sophisticated intelligence assets to build confidence with neighboring states through the expanded transparency of actions. Although extensive coordination with intelligence sources would be required for targeting, this coordination would take place regardless of the incorporation of air samplers to plan OST overflight routes. Air samplers on OST overflights to help verify the CWC could bolster worldwide efforts to counter the proliferation of chemical weapons.

Despite the benefits of this proposal, the problems encountered in its implementation would be varied. The shift of intent for the Open Skies from confidence building to verification may be unacceptable to many signatories, possibly forcing renegotiation of the OST.[83] The memberships of the OST and CWC are incompatible and application of the use of air samplers would therefore be uneven. Although air samplers might make it more difficult to cheat on the CWC, the timing provisions for

[83] The Defense Nuclear Agency notes that "Sensor configurations are specified by agreed text in the Open Skies treaty, the inclusion of an airborne CW sensor would require reopening agreed text of the treaty to renegotiation." Correspondence from LCDR Brent Ditzler, DNA, November 15, 1995.

OST overflights prevent the detection of the "smoking gun" unless host nations choose to risk detection. Finally, there is no political impetus for this proposal in 1995. Once these treaties have entered into force and the OST becomes a viable confidence-building tool, then there might be the political will to push for this expansion of the OST.

A first step in incorporating air sampling sensors into the OST sensor suite might be using this category of sensors for environmental sampling, thereby proving their utility and effectiveness. The negotiations for the OST included debate over a role of environmental monitoring for the regime, considering the capabilities of the sensing suite and the ability to cover large areas in each overflight. The preamble of the OST "envisag[es] the possible extension of the Open Skies regime into additional fields, such as the protection of the environment."[84] A study done by the Defense Nuclear Agency examines the uses of the OST sensor suite for air sampling.[85] Further, it recommends additional sensors to make the sensor suite adequate for collection scientifically useful data on environmental monitoring problems, including LIDAR and FTIR systems.[86] If the reliability and accuracy of these sensors can be proven through chemical detection in an environmental monitoring role, an expanded role as a detector of CW production may show its value.

Dr. Joseph Leonelli, an expert on these sensors, notes:

> Laser remote sensing and LIDAR techniques have been used to detect and measure the movement and concentration of air pollution near urban centers, the chemical emissions around industrial plants, and atmospheric trace chemicals in the stratosphere....The same LIDAR methods used by NASA, EPA, and several industry research groups to detect and measure the movement and concentration of air pollution near urban centers have been applied to the national security problem, of

[84] The Open Skies Treaty, Preamble, p. 1.
[85] Stupski et al, *Evaluation of the U.S. Open Skies Aircraft for Environmental Monitoring*, Prepared for the Defense Nuclear Agency, August 1, 1994.
[86] Ibid., pp. v & 13.

detecting chemical and biological warfare agents that might be used on the modern battlefield.[87]

Leonelli states that FTIR sensors have been used for national security purposes. Both LIDAR and FTIR systems are technologies with widespread use, being developed by many different nations and companies, being used for atmospheric research, trace gas detection, and atmospheric aerosol studies.[88]

Because of the timing problem of detecting CW production with an OST overflight, the argument for air samplers would need to focus on deterrence rather than detection. In either case, air samplers would enhance CW counterproliferation efforts. As Smithson and Krepon comment, "Broad area searches could further enhance deterrence by increasing the likelihood – or at least the concern of potential cheaters – that prohibited activities would be detected."[89] If air samplers on OST aircraft can deter would-be CW producers, then they can be effective at CW counterproliferation.

Some questions involving this proposal still need to be addressed. How much will sensors and operator training cost? Will the funding come from the Open Skies regime or the other agreements which it benefits? How difficult will the negotiation of sensors, sensing parameters, and chemicals constituents sensed for be? Will this intrusive measure violate U.S. or other nation's laws? Could the data provided be used for industrial espionage by the overflying party, and if so, how are host states protected from this problem? These are not easy questions. As far as arms control financial issues go, if air samplers can be incorporated into the OST regime, financial benefits would be reaped by the OPCW inspectorate. The other issues are answerable, and will be solved when these sensors are added to the OST.

[87] Leonelli, "Dual-Use Applications of Laser Remote Sensing to the Military Battlefield and Environmental Monitoring," p. 1.
[88] Correspondence with Leonelli, November 30, 1995.
[89] Smithson & Krepon, eds., *Open Skies, Arms Control and Cooperative Security*, p. 239.

Only a few years ago, the development of LIDAR and FTIR for air sampling appeared bleak. The post-Cold War shift in threat has changed the focus of the U.S. in national security efforts. The shift from a known, monolithic Soviet threat to a multipolar, low intensity, ephemeral threat has forced the United States to invest more into battling the spread of WMD and quelling regional conflict than focusing on a high-tech battle with the Soviets. Advances in the technologies for air sampling and concentrated efforts such as the RELIENCE and CALIOPE projects have made these sensors a viable option for airborne CW production detection mission.[90] The continued refinement of these and other technologies to pursue policies of nonproliferation and counterproliferation will increase America's ability to provide regional stability through limiting WMD.

The Open Skies Treaty and the Chemical Weapons Convention are both based on openness, transparency, detection, deterrence, and ultimately, confidence-building. Although they differ in specifics, these shared attributes suggest that coordinating these pacts makes good sense. Writing on verification, Ronald Lehman says, "The interaction of...treaties on nuclear, conventional, and chemical arms may help not only to provide greater strategic stability but may also result in fewer incentives to cheat and in greater strength in verification. It is necessary to examine the likely provisions of all of these treaties to make certain that they work in harmony rather than conflict and that the several verification regimes avoid excessive duplication and overhead."[91]

The incorporation of air sampling sensors into the Open Skies sensor suite to help verify the Chemical Weapons Convention would be a small measure in the U.S. policy of counterproliferation. Although the CWC does not include all states in its membership, it can still be a strong and effective regime. As the membership grows for pacts such as the

[90]RELIENCE is an Army program spearheaded by Hughes to develop ground based CW battlefield detectors to protect troops; CALIOPE is a program spearheaded by the Lawrence Livermore National Laboratory to develop airborne laser and IR sensors to detect WMD production.
[91] Lehman, "Verification in the Age of *Glasnost* and Open Skies," in Tower, Brown, and Cheek, eds., *Verification: The Key to Arms Control in the 1990s*, p. 11.

CWC, BWC, and NPT, the gap narrows on the outliers – those states refusing to comply with international arms control norms. In the same manner, the incremental step of cross-treaty synergy between the OST and CWC can increasingly deter CW producers or make production of CW as a means to security that much less desirable. This proposal is a viable one; it will not happen in the near future, but renewed momentum in arms control could realize the proposal to incorporate air samplers into Open Skies sensor suites and use them to verify the Chemical Weapons Convention.

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